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PLAUSIBILITY FUNCTIONS OF IOWA VOCABULARY TEST ITEMS ESTIMATED BY THE SIMPLE SUM PROCEDURE OF THE CONDITIONAL P.D.F. APPROACH

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KNOXVILLE, TENN. 37996-0900

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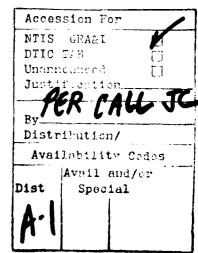
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PLAUSIBILITY FUNCTIONS OF IOWA VOCABULARY TEST ITEMS ESTIMATED BY THE SIMPLE SUM PROCEDURE OF THE CONDITIONAL P.D.F. APPROACH

ABSTRACT

Simple Sum Procedure of the Conditional P.D.F. Approach combined with the Normal Approach Method was applied for estimating the plausibility functions of the distractors of the Level 11 Vocabulary Subtest items of the Iowa Tests of Basic Skills. In so doing, the normal ogive model was adopted for the correct answers of those items, and those items were used as the substitute for the Old Test. The group of subjects consists of 2,364 students who took the Level 11 tests in 1971 through 1977. The results indicate the existence of informative distractors for certain test items, and it is confirmed that most items belong to the Informative Distractor Model rather than the Equivalent Distractor Model. The model validation study accompanied to it indicates that for most items the normal ogive model is suitable for their correct answers.

The research was conducted at the principal investigator's laboratory, 405 Austin Peay Hall, Department of Psychology, University of Tennessee, Knoxville, Tennessee. Those who worked for her as assistants include Paul S. Changas, Vicki R. Newton, Mehrdad A. Saravi, Deborah Wichlan and Cindy Wheatley-Lovoy.

I. Introduction

Three-parameter logistic model (Birnbaum, 1968) has been popular among researchers who deal with multiple-choice test items. The model is based upon the knowledge or random guessing principle, which assumes that the examinee either knows the answer or guesses randomly. In that model, each item is scored either right or wrong, depending upon whether the examinee has chosen the correct answer or one of the incorrect alternative answers. It should be noted that following the three-parameter model each incorrect alternative answer is treated as equivalent to each other, and it is implicitly assumed that, owing to the subjects' random guessing behavior, those distractors have identical operating characteristics. We will not lose any information, therefore, even if we recategorize all the incorrect alternative answers into a single category, and assign zero as the item score to those who have chosen any one of the distractors. Such a family of models belongs to the Equivalent Distractor Model.

Samejima has proposed a new family of models for the multiplechoice test item (Samejima, RR-79-4), which assumes that the examinee
chooses one of the distractors for his answer more or less
intentionally, and, therefore, each incorrect alternative answer, as
well as the correct answer, provides us with its unique information.
In those models, the examinee's random guessing behavior is still
taken into consideration, but only as the last resource when he has
no idea as to which alternative is more plausible as the answer to the
question. The plausibility function of each distractor, which is the

conditional probability assigned to the choice of that particular distractor, given ability, is the information source. If a model in the family fits our multiple-choice test data, then we shall be able to estimate the examinee's ability more accurately, using information obtained from the distractors as well as from the correct answers. Thus the multiple-choice test item is no longer a "blurred image" of the free-response test item, but it has a unique status as a test item which provides us with information that the free-response test item is not able to. Such a family of models belongs to the Informative Distractor Model.

It will be worthwhile to estimate the plausibility functions of the distractors of existing test items, to find out if, indeed, each distractor provides us with its unique information. In so doing we need some nonparametric method of estimating the operating characteristics, for we have no idea what type of mathematical function each plausibility function follows. Molding it into some parametric form from the very beginning will be harmful, therefore, more than helpful.

In the present study, a subset of the data collected on the Iowa Tests of Basic Skills was used as "existing data". It is based upon the Vocabulary Test items for Level 11. The whole set of data was obtained with the courtesy of Professor William Coffman of the University of Iowa, and was introduced in a previous research project (Samejima and Trestman, RR-80-1). For brevity, hereafter, we shall call the whole set Iowa Test Data. Its brief description will be

given in Section 2.

In estimating the plausibility function of each distractor of each test item, Simple Sum Procedure of the Conditional P.D.F.

Approach combined with the Normal Approach Method was used (cf. Samejima, Final Report, 1981). A brief description of the Simple Sum Procedure of the Conditional P.D.F. Approach and the Normal Approach Method will be given in Section 3, in comparison with other methods and approaches developed by the author.

II. Iowa Test Data

Iowa Test Data are based upon the Iowa Tests of Basic Skills, Form 6, Levels 9-14 (Hieronymus and Lindquist, 1971). These tests have been designed, constructed and revised at the College of Education of the University of Iowa since 1935, with the general school population in mind. Each of the level numbers, 9 through 14, corresponds to the age of subjects who are suitable for the subset of test items that specific level contains. Thus the tests are designed basically for the fourth through ninth graders.

There are eleven tests in the battery, each of which focuses upon a different basic skill. The numbers of test items in the eleven separate tests vary within the range of 74 through 178, including all the six levels. Table 2-1 presents these eleven tests, the numbers of test items and some other information related to their administration.

The data were collected in three different school systems in

TABLE 2-1

Iowa Tests of Basic Skills, Form 6, Numbers of Items,
Administration Sessions and Time Limits.

Test	Number of Items	Administration Session	Working Time (Minutes)
V: Vocabulary R: Reading Comprehension	114 178	First Session 85 Minutes	17 55
L-1: Spelling L-2: Capitalization L-3: Punctuation L-4: Usage	114 102 102 86	Second Session 80 Minutes	12 15 20 20
W-1: Map Reading W-2: Reading Graphs and Tables W-3: Knowledge and Use of Reference Materials	89 74 141	Third Session 85 Minutes	30 20 30
M-1: Mathematics Concepts M-2: Mathematics Problem Solving	136 96	Fourth Session 65 Minutes	30 30

TABLE 2-2

Number of Items in Each of the Three Subtests of Each of the Eleven Tests and in Total for Each of the Three Levels, 11, 12 and 13.

Test Level	٧	R	L1	L2	L3	L4	W1	W2	W3	M1	M2	Total
11	43	74	43	40	40	32	36	26	56	42	29	461
12	46	76	46	42	42	32	40	28	59	45	31	487
13	48	78	48	43	43	32	41	28	59	48	32	500
Total	82	133	82	73	73	53	67	48	99	90	61	861

the State of Iowa, in the years 1971 through 1977, using the subtests of Levels 11, 12 and 13. Table 2-2 presents the number of test items contained by each of the three levels, for each of the eleven tests. Since there are overlapping test items between two, or even three, adjacent levels, the total number of items in each test is less than the sum of the numbers of items in the three separate subtests.

In the original data, there are 2,460 examinees who took the subtests of Level 11, 2,452 who took those of Level 12, and 2,527 who took those of Level 13, to make the total number of examinees 7,439. With close examination of those original data, however, certain examinees who omitted too many test items were excluded, and the resulting "revised data" are based upon 7,246 examinees in total, with 2,364, 2,413 and 2,469 for those who took the three separate levels of subtests, respectively (cf. Samejima and Trestman, RR-80-1).

In the present study, the results of the 2,364 examinees on the Level II Vocabulary Subtest were analyzed. The choice of Level II was more or less arbitrary, but the Vocabulary Subtest was selected more intentionally, due to the factor analysis result which will be introduced in Section 5. This subtest has forty-three test items, each of which has four alternative answers, i.e., one correct answer plus three distractors.

III. Simple Sum Procedure of the Conditional P.D.F. Approach and Normal Approach Method

Samejima's methods and approaches of estimating the operating characteristics of discrete item responses were introduced in previous

research reports (Samejima, RR-77-1, RR-78-1, RR-78-2, RR-78-3, RR-78-4, RR-78-5, RR-78-6), and were summarized later (Samejima, Final Report, 1981). They are characterized by two features, i.e.,

1) estimation is made without assuming any mathematical forms for the operating characteristics of discrete item responses, and

2) estimation is efficient enough to base itself upon a relatively small set of data of, say, several hundred to a few thousand examinees.

There are two main approaches, one of which is called Bivariate P.D.F. Approach, and the other is called Conditional P.D.F. Approach. In the former approach, we approximate the bivariate distribution of the transformed latent trait \u03c4 and its maximum likelihood estimate τ , for each of the subgroups of examinees who share the same discrete item response to a specified item. Thus the procedure must be repeated as many times as the number of discrete item response categories for each item. In contrast to this, in the Conditional P.D.F. Approach, this is done for the total group of subjects. Effort is focused upon the approximation of the conditional distribution of τ , given $\hat{\tau}$, for the total group of examinees, and then the result is branched into separate discrete item response subgroups for each item. This latter approach is further categorized into three procedures, i.e., Simple Sum Procedure, Weighted Sum Procedure and Proportioned Sum Procedure. In each approach, there are three methods of approximating the conditional distribution of τ , given $\hat{\tau}$, and they are called Pearson System Method, Two-Parameter

Beta Method and Normal Approach Method, respectively.

It is appropriate to say that, theoretically, Bivariate P.D.F. Approach is a more orthodox approach, and Conditional P.D.F. Approach is a simplified version of the former. The latter approach has two big advantages, however, in the sense that the CPU time required is substantially less, and that it does not have to deal with subgroups of small numbers of subjects in approximating the joint bivariate distributions of τ and $\hat{\tau}$. It is also appropriate to say that both Two-Parameter Beta Method and Normal Approach Method are simpler versions of Pearson System Method; and yet the latter two methods have an advantage of using only the first two estimated conditional moments of τ , given $\hat{\tau}$, whereas the former requires the additional third and fourth conditional moments, whose estimations are less accurate compared with those of the first two conditional moments.

Our past experience with simulated data indicates that in many cases even by using the combination of relatively simplified approach and method we can estimate the operating characteristics fairly accurately. For this reason and because of the advantages described in the preceding paragraph, our choice of approach and method in the present study is the combination of the Simple Sum Procedure of the Conditional P.D.F. Approach and the Normal Approach Method.

Let θ be ability, or latent trait, which assumes any real number, and k_g be any discrete response category to item g. We assume that there is a set of test items measuring θ whose characteristics are known. This set of test items is called Old Test.

Let $I(\theta)$ denote the test information function of the Old Test of n such items. The transformation of θ to τ is made by

(3.1)
$$\tau = c_1^{-1} \int_{-\infty}^{\theta} [I(t)]^{1/2} dt + c_0,$$

where $^{C}_{0}$ is an arbitrary constant for adjusting the origin of $^{\tau}$, and $^{C}_{l}$ is an arbitrary constant which equals the square root of the test information function, $^{I*(\tau)}$, of $^{\tau}$, so that we can write

(3.2)
$$C_1 = [I*(\tau)]^{1/2}$$

for all τ . This transformation will be simplified if we use a polynomial approximation to the square root of the test information function, $I(\theta)$, which is accomplished by using the method of moments. Thus (3.1) can be changed to the form

(3.3)
$$\tau \doteq c_{1}^{-1} \sum_{k=0}^{m} \alpha_{k} (k+1)^{-1} \theta^{k+1} + c_{0}$$

$$= \sum_{k=0}^{m+1} \alpha_{k}^{*} \theta^{k} ,$$

where α_k (=0,1,...,m) is the k-th coefficient of the polynomial of degree m approximating the square root of $I(\theta)$, and α_k^* is the new k-th coefficient which is given by

(3.4)
$$\alpha_{k}^{*} \begin{cases} = c_{0} & k = 0 \\ = (c_{1}k)^{-1} \alpha_{k-1} & k = 1, 2, ..., m+1 \end{cases}$$

The first through fourth conditional moments of τ , given $\hat{\tau}_S$, can be obtained from the density function, $g^*(\hat{\tau})$, of $\hat{\tau}$ and the constant C_1 by the following four formulae.

(3.5)
$$E(\tau | \hat{\tau}_{s}) = \hat{\tau}_{s} + C_{1} \frac{-2 d}{d\hat{\tau}_{s}} \log g * (\hat{\tau}_{s}) .$$

(3.6)
$$\operatorname{Var.}(\tau | \hat{\tau}_s) = C_1^{-2} [1 + C_1^{-2} \frac{d^2}{d\hat{\tau}_s^2} \log g^*(\hat{\tau}_s)]$$
.

(3.7)
$$E[\{\tau - E(\tau | \hat{\tau}_s)\}^3 | \hat{\tau}_s] = C_1^{-6} \left[\frac{d^3}{d\hat{\tau}_s^3} \log g^*(\hat{\tau}_s) \right].$$

(3.8)
$$E[\{\tau - E(\tau | \hat{\tau}_s)\}^4 | \hat{\tau}_s] = C_1^{-4} [3 + 6C_1^{-2} \{\frac{d^2}{d\hat{\tau}_s^2} \log g^*(\hat{\tau}_s)\} + 3C_1^{-4} \{\frac{d^2}{d\hat{\tau}_s^2} \log g^*(\hat{\tau}_s)\}^2 + C_1^{-4} \{\frac{d^4}{d\hat{\tau}_s^4} \log g^*(\hat{\tau}_s)\}].$$

Note that in the above formulae the first moment is about the origin, while the other three are about the mean. The two coefficients, β_1 and β_2 , and Pearson's criterion $^{\kappa}$ are obtained by

$$\beta_1 = \mu_3^2 \, \mu_2^{-3}$$

(3.10)
$$\beta_2 = \mu_4 \ \mu_2^{-2} \ ,$$

and

(3.11)
$$\kappa = \beta_1 (\beta_2 + 3)^2 [4(2\beta_2 - 3\beta_1 - 6)(4\beta_2 - 3\beta_1)]^{-1}$$
,

by substituting μ_2 , μ_3 and μ_4 by $Var.(\tau | \hat{\tau}_s)$, $E[\{\tau - E(\tau | \hat{\tau}_s)\}^3 | \hat{\tau}_s] \text{ and } E[\{\tau - E(\tau | \hat{\tau}_s)\}^4 | \hat{\tau}_s] \text{, respectively, which are obtained by formulae (3.6), (3.7) and (3.8).}$

In the Simple Sum Procedure of the Conditional P.D.F. Approach, the operating characteristic, $P_{kg}(\theta)$, of the discrete item response k_g of an "unknown" item g is estimated through the formula

$$(3.12) \qquad \hat{P}_{k_{g}}(\theta) = \hat{P}_{k_{g}}^{*}[\tau(\theta)] = \sum_{s \in k_{g}} \phi(\tau | \hat{\tau}_{s}) [\sum_{s=1}^{N} \phi(\tau | \hat{\tau}_{s})]^{-1},$$

where s (=1,2,...,N) indicates an individual examinee, and $\phi(\tau|\hat{\tau}_s)$ denotes the conditional density of τ , given $\hat{\tau}_s$. This conditional density is estimated by using the estimated conditional moments of τ , given $\hat{\tau}_s$. In the Normal Approach Method, $\phi(\tau|\hat{\tau}_s)$ is approximated by the normal density function, using the first two estimated conditional moments of τ , given $\hat{\tau}_s$, which are given by (3.5) and (3.6), respectively, as its parameters.

IV. Old Test

In this study, we need some suitable substitute for the Old

Test, since there is no set of test items measuring the same

vocabulary ability whose characteristics are known. To handle this

situation, we use the Level 11 Vocabulary Subtest itself twice, i.e., first as the Old Test and later as the set of "unknown" test items.

On the first stage, each item is rescored as "right" or "wrong", i.e., dichotomously, and the normal ogive model on the dichotomous response level is assumed. We accept this model tentatively, and the item parameter estimation is made for each of the forty-three test items. On the second stage, these forty-three test items are treated as they are, i.e., as multiple-choice test items with polychotomous item responses. The "unknown" operating characteristic is to be estimated, therefore, for each of the four alternative answers of each item. As the result, we will obtain the estimated plausibility functions of the distractors for each item. In addition to this, the estimated operating characteristic of the correct answer of each item is compared with the hypothesized normal ogive function as a part of the model validation process, which will be introduced in Section 8. If the model is validated, then we will accept the estimated operating characteristics of the incorrect alternative answers as the estimated plausibility functions of the distractors. If not, we will examine the invalidated test items, and either assume more suitable models for them or discard them, to produce a new Old Test and repeat the estimation process all over again.

The item characteristic function, $P_g(\theta)$, of item g in the normal ogive model is given by

(4.1)
$$P_g(\theta) = (2\pi)^{-1/2} \int_{-\infty}^{a_g(\theta-b_g)} e^{-\frac{u^2}{2}} du$$
,

where a_g is the item discrimination parameter and b_g is the item difficulty parameter.

V. Item Parameter Estimation for the Old Test Items Following the Normal Ogive Model

It is assumed that the response tendencies of our 2,364 examinees behind the forty-three items of the Level II Vocabulary Subtest have a multinormal distribution as their joint distribution. If there exists a single common factor behind these forty-three response tendencies, then we shall be able to operationally define the factor as the vocabulary ability for the contents of this specific subtest. As the result of this assumption, the ability distribution for these 2,364 subjects will also be normal, and we shall define the origin and the unit of the ability scale as the mean and the standard deviation of this normal distribution.

The tetrachoric correlation coefficient is obtained for each pair of test items, using the program written by the author. The resulting inter-item correlation matrix is given as Table 5-1. Those tetrachoric correlation coefficients were adjusted for the unbiasedness, which means that each value is a little less in the absolute value than the straightforward sample correlation coefficient. The item numbers in this table, which range from 24 to 66, are the same as those used in the actual Iowa Vocabulary Test. We can see in this table that all the correlation coefficients are

TABLE 5-1

Tetrachoric Inter-Item Correlation Matrix for the Forty-Three Old Test Items.

0521627 0957218	0.1669041 0.3511450	1416636 3018401	0.1437644 0.2530969	0.1889279 0.3270504	2059265	2053178 3898572	.1786546	.2216352 .3538963	1365902 1.2510669	0.1441173 0.2783180	1.1234629 1.2207608	2025431	0.12 49567 0.1562499
0.0940295 0.	1407813	.3033748 0.1	0.2609838 0.	0.2386805 0.	9.4006749 0.	0.3600930 0.	0.3668591 0.	0.3 645686 0.	0.1976514 0.	0.2115260 0.	0.1558645 0.	0.2299038 0.	0.2234328 0
0.094864 0.		.2615715 0.3	0.1911705 0.	0.2959691 0.	0.2840456 0.	0.3058905 0.	0.3633990 0.	0.2996526 0.	0.1877518 0.	0.2498644 0.	0.1744483 0.	0.1884488 0.	0.1628274 0
0.1140842 0	0.2202375 0 0.21609^^ U	0.1656163 0 0.1941416 0	0.1623291 0 0.1787614 0	0.1795844 0.1686400	0.2110311	0.2231665 0.2884923	0.2301161 0.2833290	0.2156547 0.2241532	0.1305700 0.0622953	0.1551747 0.1542370	0.1145293 0.1233405	0.1 888266 0.2452559	1.0000000 0.1095014
0.1 666906 0.0974146	0.3102316	0.2768288 0.3359429	0.3795376 0.3150405	0.2896129 0.2965080	0.4379924	0.3409578 0.3648472	0.3553232 0.3858331	0.4052198 0.3216242	0.2758186 0.2365741	0.3536839	0.2669045	1.000000 0.2835466	3 0.1888266 5 0.1788514
0.0422507	0.2353001	0.2051280 n.2697897	0.2010145 0.2733328	0.2744033	0.3174860	0.2764890 0.3482534	0.3087924 0.3867788	0.3852987 0.4251198	0.1325260 0.1580129	0.1936837 0.3059496	1.0000000	0.2 669045 0.3145872	0.1145293 0.1815085
0.1263537	0.3869971	0.2395093	0.2840921	0.3123369	0.3793164	0.3488467	0.3240136	0.3801177	0.2901961	1.0000000	0.1936837	0.3536839	0.1551747
0.9	0.1738785	0.2608959	0.0936628	0.1163605	0.1815295	0.2611812	0.2272375	0.1889941	0.0843228	0.1685529	0.1757793	0.1470114	
0.1147743	0.3018852	0.2001185	0.2418728	0.2493849	0.3106628	0.3074893	0.3000724	0.3194075	0.2218246	0.2123570	0.2143735	0.2466872	
0.0414962	0.2063613	0.2627316	0.2561964	0.2549831	0.2050717	0.2314577	0.2859124	0.3227525	1.000000	0.2901961	0.1325260	0.2758186	0.1305700
0.1012570	0.2524251	0.1694981	0.2209406	0.1970057	0.2085356	0.2814463	0.2319999	0.2528411	0.1985462	0.2011869	0.1608473	0.2218262	0.1474723
0.1051888	0.2397097	0.2414441	0.2665346	0.2383689	0.3382834	0.3330652	0.3275992	0.3074806	0.1731465	0.2507920	0.1481825	0.2979951	0.1394995
0.0791268	0.4723870	0.3614268	0.3523675	0.4256291	0.4914476	0.4563088	0.4319209	1.0000000	0.3227525	0.3801177	0.3852987	0.4052199	0.2156547
0.0841067	0.4040413	0.3866972	0.3462861	0.3389978	0.4113224	0.4276418	0.4888046	0.3902752	0.2146162	0.2872126	0.2915918	0.3360881	0.1923636
0.1193218	0.3482097	0.2513617	0.2628030	0.2550166	0.3612836	0.4469891	0.4260510	0.4306055	0.2225023	0.3371662	0.2730431	0.2985572	0.1881883
0.038 8065 0.0969695 0.1062381	0.2911807 0.3326808	0.3743591 0.2953451 0.2355658	0.3490089 0.1483133 0.2899752	0.3809277 0.1824743 0.3302134	0.4186257 0.2922356 0.3510854	0.3736315 0.3736315 0.3715844	1.0000000 0.2909091 0.3145185	0.431 9209 0.2619942 0.3530134	0.2859124 0.1796977 0.1616884	0.3240136 0.2023376 0.2314695	0.33 20823 0.2320823 0.2157425	0.353232 0.2683623 0.2391557	0.2301161 0.0881515 0.1841699
0.1308296 0.0769941 0.1835701	0.4621344 0.3204827 0.3668423	0.3877187 0.2492060 0.3188826	0.3204204 0.3204204	0.3869810 0.3039388 0.3916838	0.4401058 0.3190408 0.4316805	1,0000000 0,3496628 0,4558250	0.5107167 0.3380155 0.4009839	0.4563088 0.3345647 0.4848578	0.2314577 0.1616717 0.3108866	0.3488467 0.2404135 0.3148485	0.27 6488 0 0.23 67042 0.29 68 507	0.3409578 0.2379254 0.3689912	0.2231665 0.1814064 0.1924882
0.1570123 (0.1097514 (0.0487050 (0.4331321	0.3538478	0.3472835	0.3765965	1.0000000	0.4401058	0.4188257	0.4914476	0.2050717	0.37931 64	0.3166385	0.4379924	0.2110311
	0.4215021	0.3180952	0.3642446	0.3769960	0.4168268	0.4569916	0.4537662	0.4908680	0.2720072	0.3326744	0.2962021	0.3809565	0.2251055
	0.2594044	0.2385659	0.1977642	0.1915701	0.2630230	0.3086860	0.2905576	0.2418741	9.1105742	0.2373930	0.1673184	0.1879780	0.2208328
0.1512896	0.4043010	0.2828172	0.2872279	1.000000	0.3765965	0.3869810	0.3809277	0.4256291	0.2549831	0.3123369	0.2744033	0.2896129	0.1795844
0.0	0.0879300	0.0294017	0.0419975	0.0435011	0.0250741	0.0589741	0.1105213	0.0	0.1112141	0.0807523	0.0870309	0.0325619	0.1183909
0.1478593	0.3438944	0.2958089	0.2582905	0.2843454	0.3420221	0.3985187	0.3561259	0.3710800	0.1993886	0.2720736	0.2093262	0.2656740	0.1931034
0.0	0.2983024 0.3560494 0.2300913	0.3012 569	1.0000000	0.2872279	0.3472835	0.3672472	0.3490089	0.3523675	0.2561964	0.2982062	0.2010145	0.3795376	0.1 623291
0.1008802		0.2787725	0.2992719	0.2799463	0.3862715	0.3474293	0.3321094	0.4286994	0.2306693	0.2982062	0.2646528	0.3400669	0.1809332
0.1463099		0.1909955	0.1725914	0.2916188	0.2805754	0.3208684	0.2820422	0.2631146	0.1589384	0.1726849	0.2039005	0.2076496	0.1348752
0.0355945	0.2967272	1.000000	0.3012569	0.2828172	0.3538478	0.3877187	0.3743591	0.3614268	0.2627316	0.2395093	0.2051280	0.2766286	0.1656163
0.1354520		0.1340445	0.1909248	0.2384553	0.2857870	0.2643684	0.3262929	0.2674731	0.1860362	0.1787663	0.1353260	0.2140031	0.1608883
0.0440173		0.1918052	0.2322044	0.1991724	0.2112995	0.2821245	0.2476018	0.1792548	0.0318161	0.1684636	0.1649603	0.2073274	0.0745582
0.1172895	1.0000000	0.3589825	0.2983024	0.4043010	0.4331321	0.4621344	0.4306780	0.4723870	0.2063613	0.3869971	0.2353001	0.3102316	0.1344541
0.1123604	0.2982017	0.2106639	0.2907348	0.2223309	0.3228583	0.2440570	0.2532074	0.3595721	0.2198991	0.2784293	0.2967452	0.3087468	
0.0808601	0.2034523	0.1618953	0.1583477	0.1840936	0.2145590	0.2442756	0.2574999	0.1916677	0.1054485	0.1604320	0.1635056	0.1368962	
1.000000	0.1172895	0.0355945	0.0	0.1512896	0.1570123	0.1308286	0.0388065	0.0791268	0.0414962	0.1263537	0.0422507	0.1 666906	0.1140842
0.1118264	0.3581565	0.2914753	0.2076449	0.2941492	0.3117588	0.3498451	0.4654391	0.3291997	0.1728950	0.2257789	0.2961692	0.2434325	0.2128683
0.1547318	0.3178028	0.2303956	0.1964741	0.2901977	0.3253116	0.3273282	0.3847518	0.3209836	0.1592304	0.1930904	0.1707014	0.2475240	0.1839930
*~	52	92	2.7	52	2	30	31	32	33	34	35	36	37
.; •	÷			*	::	• • • • • • • • • • • • • • • • • • •	I tem	. t e #	# **		2.	::	

TABLE 5-1 (Continued)

1 tem 38	# #	330 0.3668591 0.3645686 0.1976514 0.2115260 0.1558645 0.2299038 0.2234328 1.0000000 0.1429929 105 0.2389997 0.3310460 0.2326127 0.2096250 0.3448594 0.3059342 0.2377261 0.2589078 0.2695881 167 0.2994692 0.3844661 0.3015227 0.2794068
Item 39	t	78 0.17 86546 0.2216 352 0.1365902 0.1441173 0.1234629 0.2025431 0.1249567 0.1429929 1.0000000 748 0.1333147 0.2038011 0.1161188 0.0808029 0.1153775 0.1863360 0.1220191 0.1665660 0.1863103 108 0.1486674 0.1929189 0.1541105 0.1383742
Item 40	•	51 0.4654391 0.3291997 0.1728950 0.2257789 0.2861692 0.2431325 0.2128663 0.3502894 0.2145775 291 0.2925382 0.4030980 0.1649464 0.1643657 0.2880116 0.2873516 0.2376347 0. 16275 0.344749 595 0.2507302 0.3536747 0.3168090 0.2835407
It •		770 0.253 2074 0.359 5721 0.2198991 0.2784293 0.2967452 0.3087468 0.1344541 0.2366863 0.1648121 596 0.1988061 0.2809126 0.2506363 0.1552910 0.2637284 0.2037097 0.1818456 0.1807275 0.2568724 464 0.2526426 0.3195252 0.2182366 0.1911278
Item 42		584 0.3265929 0.2674731 0.1860362 0.1767663 0.1353260 0.2140031 0.1608883 0.2435099 0.1261244 282 0.1368172 0.2638839 0.0656423 0.0884337 0.2021883 0.2320591 0.0834655 0.1823223 0.1863967 957 0.1898296 0.2779961 0.2104062 0.1705992
Item 43		293 0.3321094 0.4286994 0.2306693 0.2982062 0.2646528 0.3400669 0.1809332 0.3339757 0.1789445 829 0.2447605 0.3528562 0.2352535 0.2072157 0.3470572 0.2740467 0.2104777 0.2122179 0.3132954 875 0.2823302 0.3514956 0.2016461 0.2476575
1 to 8 44		441 0.1105213 0.0 0.1112141 0.0807523 0.0870309 0.0325619 0.1183909 0.1171880 0.0219309 342 0.0 0.1155627 0.0 0.0776421 0.1090536 0.0869740 0.0500838 0.1129652 0.1173692 678 0.0830708 0.0497162 0.1269371 0.1205247
Item 45	•	116 0.4537662 D.4908680 0.2720072 0.3326744 0.2962021 0.3809565 0.2251055 0.3567438 0.1844969 517 0.2577132 0.4694223 0.2758561 0.2492294 0.3466231 0.3614307 0.2336399 0.2736517 0.4009559 245 0.3116479 0.3664438 0.3228709 0.2886705
Item 46		628 0.33 00155 0.3345647 0.1616717 0.2404135 0.2367042 0.2379254 0.1814054 0.3224105 0.1687748 000 0.2673540 0.3620821 0.2238830 0.1943653 0.2466980 0.2623428 0.1866713 0.2610922 0.3159820 381 0.2740616 0.3184567 0.2342283 0.2603487
Item 47	5	115 0.290901 0.2619942 0.1796977 0.2021376 0.2320823 0.2683623 0.0881515 0.2389997 0.1333147 540 1.000000 0.2885007 0.2199659 0.1883901 0.2035143 0.2182809 0.1399489 0.2492377 0.2461383 156 0.1880487 0.2688717 0.2107088 0.2084355
Item 48	:	418 0.4888046 0.3902752 0.2146162 0.2872126 0.2915918 0.3360881 0.1923636 0.3310460 0.2038011 821 0.2886007 1.0000000 0.2157584 0.2176320 0.3473549 0.3545865 0.2338815 0.3510045 0.3519166 393 0.2865637 0.3784319 0.3467628 0.3470464
Item 49	=	463 0.2319999 0.2528411 0.1985462 0.2011869 0.1608473 0.2218262 0.1474723 0.2226127 0.1161188 830 0.2199659 0.2157584 1.0000000 0.1120228 0.2689650 0.1619977 0.1504393 0.1432235 0.2080073 782 0.2332017 0.2219161 0.1250271 0.2016200
Item 50	•	812 0.2272375 0.1889941 0.0843228 0.1685529 0.1757793 0.1470114 0.0887620 0.2096250 0.0808029 663 0.1883901 0.2176320 0.1120228 1.0000000 0.1709983 0.1925303 0.1386739 0.1208697 0.1277093 470 0.1374577 0.2361078 0.1806028 0.1467888
item 51	•	334 0.3867788 0.4251198 0.1580129 0.3059496 0.2947266 0.3145872 0.1816085 0.3448594 0.1153775 980 0.2035143 0.3473549 0.2689650 0.1709963 1.0000000 0.2831964 0.1421094 0.2135832 0.3192759 724 0.2753877 0.2908283 0.2691258 0.3053756
Item 52		472 0.3858331 0.3216242 0.2365741 0.2599618 0.1490471 0.2835466 0.1788514 0.3059342 0.1863360 428 0.2182367 0.2448871 0.283509 0.3545865 0.1619977 0.1925303 0.2831964 1.0000000 0.2202279 0.3112367 0.2448871 995 0.3157049 0.346590 0.2840387 0.2448871

TABLE 5-1 (Continued)

Ø

0.1 220191	0.1665660	0.1863103	0.2072340	0.1639503	0.1881806	0,0977928	0.1652585	0.2173674	3.7086108	0.1486674	0.19 2 9189	0.1541105	0.1383742
0.2592089	0.2663625	1.0000000	0.3112544	0.1291235	0.204110	0,2500674	^.2055026	0.2173674	9.4093169	0.3997143	0.2994606	0.2992650	
0.2377261	0.2589978	2 595881	0.2815677	0.1633320	0.1669794	0.1911867	0.2145010	0.2498556	0.3736467	0.2 9946 92	0,3848661	9,3015227	0.2 794068
0.2206587		3.2663525	0.25**223	0.2537286	0.2647516	0.2165787	°.2253239	0.2774631	0.2980400	0.2585236	0,3195007	7,3065740	0.3401196
0.1 095014	0.1628274	0.156 2499	0,1839930	0.1030289	0.0745 582	0.1348752	0.1931034	9,2208328	0,1924887	0.1841699	0.1881883	0,1394995	0.1375532
1.0000000	0.2205587	0.25820 9	0,2099584	0.1066204	0.1534060	0.1820783	0.2276678	9,1866807	0,2277706	0.1645519	0.1844735	0,2210034	
0. 2452559 0.2202279), 1984488 C (112367	9,2440605	0.2475240 0.2515507	0.1368962 0.1469466	0.2073274 0.1984274	0.2076498 0.2431908	0.2 6567 40 0.3320963	0.1879780 0.2100291	0.3689912 0.3663985	0.2391557 0.3157049	0,2985572 0,3466590	0.29 7995 1 0.28 4 038 ⁷	0.2462310
0.1233465 0.1421094	0.1744483	0.2297608 0.2192759	0.1707014 0.2519147	0.1635056 0.1964201	0.1648603 0.1905451	0.2039005 0.2451428	0.2093262 0.2583975	0.1673/84 0.2627359	9.2968507 0.3123724	0.2157425	0.273 04 31 0.2908283	0.1481925 0.2691258	0.2143735
0.1542370	0.2498644	0.2783180	0.1930904	0.1604320	0.1684636	0.1726849	0.2720736	6.2373930	0.31484P5	0.2314695	0.3371662	0.2507920	0.2123570
9.1386739	0.1208697	0.1277093	0.1252367	0.1213605	0.0892202	0.1395161	0.2300842	0.2128902	0.2123470	0.1374577	0.2361079	0.1806028	0.1467888
9.1710963	0.3401186	0.2460995	0.2578923	0.1990110	0.2268693	0.2377980	0.2901183	0.3079649	0.3612609	0.3634993	0.4104996	0.3592387	1.0000000
0.0622953	0.1877618	0.2510669	0.1592304	6,1054485	0.0318161	0.1589384	0.1993886	0.1105742	0.3108866	0.1616884	0.2225023	0.1731465	0.2218246
0.1504393	0.1432235	0.2080073	0.1794605	0,0997483	0.1741830	0.2029316	0.2014714	0.1705502	0.2921782	0.2332017	0.2219161	0.1250271	0.2016200
0.2210034	0.3065740	0.2992650	0.2570719	0,1735153	0.2818347	3.2414699	0.3301693	0.2351147	0.3864884	0.2868487	0.3399313	1.0000000	0.3592387
0.2241532	0.2996526	0.3538963	0.3209836	0.1916677	0.1792548	0.2631145	0.3310246	0.2418741	0.4848578	0.3530134	0.4306055	0.3074806	0.3194075
0.2339815	0.3510045	0.3619166	0.3179635	0.2650771	6.2431626	0.2069136	0.3310246	0.3349856	0.3979393	0.2865637	0.3784319	0.3467628	0.3470464
0.1844735	0.3195007	0.2984606	0.3441804	0.2316697	0.2074802	0.3119730	0.4048109	0.2893988	0.4715139	0.3941100	1.0000000	0.3399313	0.4104996
0.2833290	0.2492377	0.2461383	0.3847518	0.2574999	0.247 6018	0.2820422	0.3561259	0.2905576	0.400 9839	0.3145185	0.4260510	0.3275992	0.3000724
0.1399489	0.2492377	0.2461383	0.2054303	0.1315812	0.2208011	0.1757727	0.2380371	0.1982231	0.2681156	0.1880487	0.2688717	0.2107088	0.2084355
0.1645519	0.2585236	0.3097143	0.2546757	0.1998464	0.2453878	0.2322525	0.3258481	0.2562265	0.4237980	1.0000000	0.3941100	0.2886487	0.3634993
0.284923	0.3058905	0.3898572	0.3273282	0.2442756	0.2821245	0.3208684	0.3985187	0.3086860	0.4558250	0.3715844	0.4469891	0.3330652	0.3074893
0.1866713	0.2610922	0.3159820	0.2650417	0.2130170	0.2281064	0.2071525	0.2599953	0.2225652	0.3689391	0.2740616	0.3184567	0.2342283	0.2603487
0.2277706	0.2980402	0.4093169	0.3666080	0.2051080	0.2403041	0.3442755	0.3869429	0.2952332	1.000000	0.4237980	0.4715139	0.3864884	0.3612609
0.236399	0.2736517	0.2745722	0.3253116	0.2145590	0.2112995	0.2805754	0.3420221	0.2630230	0.4316805	0.3510854	0.3612836	0.3382834	0.3106628
0.236399	0.2736517	3.4009559	0.3485566	0.2142183	0.2246974	0.3010343	0.3369702	0.3262717	0.4496245	0.3116479	0.3664438	0.3228709	0.2886705
0.1866807	0.2794681	0.2173674	0.2746774	0.2335693	0.1638975	0.2438684	0.2573890	1.0000000	0.2992332	0.2562265	0.2893988	0.2351147	0.3079649
0.1 6%6400	0.2959691	0.3270504	0.2901977	0.1840936	0.1991724	0.2916188	0.2843454	3.1915701	0.3916838	0.3302134	0.2550166	0.2383689	0.2493849
0.0500838	0.1129652	0.1173692	0.0945367	0.1417853	0.1032121	0.0520890	0.0379209	0.0729739	0.0408678	0.3830708	0.0497162	0.1269371	0.1205247
0.2276678	0.2253298	0.2955026	0.2976972	0.1605583	0.1981364	0.3262665	1.0000000	0.7673890	0.3859429	0.3258481	0.4048109	0.3301693	0.2901183
0.1787614	0.2122179	0.2530969	0.1964741	0.1583477	0.2322044	0.1725914	6.25.2905	0.1977542	0.3204204	0.2899752	0.2628030	0.2665346	0.2418728
0.2104777	0.2122179	0.3132954	0.2482536	0.1337487	0.1335903	0.2353939	9.3208%1	0.2033489	0.4161875	0.2823302	0.3514956	0.2016461	0.2476575
0.1820783	0.2165787	0.2500649	0.1848463	0.1575111	0.1349447	1.0060000	0.326766%	0.2438684	0.3442755	0.2322525	0.3119730	0.2414699	0.2377980
0.1941416	0.2615715	0.3018401	0.2303956	0.1308903	0.191 805 2	0.1909965	0.2953089	0.2385659	0.3188826	0.2355658	0.2513617	0.2414441	0.2001185
0.3834655	0.1823223	0.1863967	0.1765532	0.1308903	0.1224953	6.1888999	0.2642354	0.1909081	0.2606957	0.1898296	0.2779961	0.2104062	0.1705992
0.1534060	0.2647516	0.2054110	6.2290467	0.1867430	1.0000000	6.1349447	0.1981364	0.1638975	0.2403041	0.2453878	0.2074802	0.2818347	0.2268693
0.2160906	0.3460375	0.3511450	0.3178028	0.2034523	0.233717	0.2300913	0.3438944	0.2594044	0.368423	0.3325808	0.3482097	0.23 97097	0.3018852
0.1818456	0.1807275	0.2558724	0.2041599	9.0500201	6.2327955	0.1675771	0.2465269	0.1800957	0.3213464	0.252f426	6.3195252	0.2182366	0.1911278
0.1066204	0.2537286	0.1291235	0.2043467	1.000000	0.1867430	0.1575111	0.1605583	0.2335693	0.2051080	0.1998464	0.2316697	0.1735153	0.1990110
0.2375347 0.2099584	0.0948864 0.3206275 0.2527223	0.3444749 0.3444749 0.3112044	9.1547318 0.3478146 1.0000000	0.0808601 0.2433125 0.2043467	9.2440173 3.2513903 0.2290467	0.1463099 5.2652416 5.1848463	0.1409693 0.3309227 0.2976972	0.0487050 0.2558707 0.2746774	0.1835701 0.3061595 0.3666080	0.10 62 381 0.25073 02 0.254 6757	0.1193218 0.3536747 0.3441804	0.1051888 0.3168090 0.2570719	0.1147743 0.2835407 0.2578923
53	3 .	\$	\$	÷	8	0 -	9 *	5	29	6	4	6.5	\$9
	:	*		\$	# • •	*	3	∰ 6 □	•	*	\$0 \$0		•
••	••	• •	• •		• •	• •		•	• •	• •	. .	**	b4

non-negative, the fact which indicates the existence of a strong, dominating common factor. This inter-item correlation matrix, R, was subtracted by the covariance matrix of the unique factor matrix, V, and the resulting matrix was factor analyzed, using the computer program for principal factor solution in Biomedical Computer Programs Multivariate Analysis Series 4 (BMDP4M). Actually the matrix (R-V) was obtained by a usual iterative estimation of each of the n communalities, with the squared multiple correlation of each variable with all other variables as its initial estimate.

The same procedure was applied for each of the other ten Level
11 Subtests, and the resulting sets of eigenvalues are shown in
Table 5-2*, except for those of the Level 11 Reading Comprehension
Subtest (R)**. Inspection of this table tells us that Vocabulary

^{*}The computer program is written in the way that we can adjust the accuracy of the estimation of correlation coefficients in certain ways. After one way was applied for all the subtests, it was redone for Vocabulary Subtest by increasing the accuracy for a certain range of correlation coefficients, and the new result was used in the present study. Although the discrepancies are small, in this sense the results of the other nine subtests are not exactly comparable to the result of the Vocabulary Subtest. Also, the numbers of common factors used for the reestimations of the communalities are much less for the other subtests than 40 which was used for the Vocabulary Subtest, i.e., 15, 15, 13, 15, 10, 15, 20, 15 and 15, respectively.

^{**}For this specific subtest, we obtained the message that the matrix is not positive semi-definite. It is suspected that there are a substantial number of zeros in the correlation matrix because of the unbiasedness adjustment, and this may be one of the reasons for the message.

TABLE 5-2

Eigenvalues of the Matrix (R-V) for Each of the Ten Level 11 Subtests
Obtained As the Results of the Principal Factor Solution of Factor
Analysis.

						ests				
__	٧	L1	L2	L3	L4	¥1	₩2	¥3	M1	#2
1	11.4174	12.3175	10.5823	11.5618	8.4561	7.8066	6.5457	15.1236	10.2474	7.2963
2	1.0398	1.5332	1.9527	2.1354	1.5431	1.9619	1.0297	4.2759	1.4570	1.4043
3	0.7704	1.0122	1.5139	1.6246	0.9682	0.8137	0.9838	0.9698	0.9571	0.7383
4	0.6788	0.8248	1.0949	1.2001	0.7260	0.7445	0.7495	0.8879	0.7146	0.6322
5	0.6395	0.7283	0.7010	0.9655	0.7014 0.5827	0.5331	0.6671 0.57 8 9	0.8028 0.7542	0.6729 0.5537	0.5763 0.5334
7	0.6023	0.6048	0.6257	0.7772	0.5389	0.4299	0.5468	0.6152	0.5184	0.4784
à l	0.5512	0.5207	0.5439	0.5810	0.4632	0.4107	0.4518	0.5983	0.4542	0.4523
9	0.5248	0.4739	0.4916	0.4825	0.4486	0.3541	0.3707	0.5493	0.4138	0.4165
10	0.5084	0.4207	0.4478	0.4174	0.3925	0.3069	0.3143	0.5262	0.4038	0.3271
11	0.4801	0.3885	0,3990	0.3530	0.3589	0.2329	0.2667	0.5190	0.3784	0.2913
12	0.4458	0.3780	0.3545	0.3239	0.3332	0.2237	0.2318	0.4880	0.3544	0.2609
13	0.4471	0.3330	0.3434	0.2952	0.3009	0.1719	0.2151	0.4504	0.3372	0.2399
14	0.4133	0.2928	0.3209	0.2158	0.2859,	0.1617	0.1874	0.4165	0.3239	0.2045
15	0.3966	0.2882	0.2981	0.2042	0.2093	0.1427	0.1487	0.3635	0.2803	0.1736 0.1218
16 17	0.3725	0.2069	0.2351	0.2022	0.1165 0.1101	0.1234 0.1139	0.0849 0.0508	0.3516	0.2060	0.0705
18	0.3444	0.1783	0.1903	0.1387	0.0977	0.1003	0.0406	0.3018	0.1692	0.0645
19	0.3188	0.1597	0.1435	0.1329	0.0747	0.0761	0.0236	0.2837	0.1475	0.0384
20	0.3065	0.1351	0.1409	0.1015	0.0638	0.0629	0.0183	0.2500	0.1428	0.0237
21	0.2673	0.1082	0.1127	0.0892	0.0544	0.0441	0.0067	0.2042	0.1339	0.0228
22	0.2574	0.0972	0.0913	0.0702	0.0391	0.0177	-0.0112	0.1980	0.1002	0.0153
23	0.2413	0.0873	0.0893	0.0507	0.0277	0.0070	-0.0228	0.1910	0.0947	-0.0091
24	0.2286	0.0742	0.0706	0.0271	0.0095	-0.0086	-0.0431	0.1778	0.0768	-0.0218
25	0.2161	0.0645	0.0512	0.0176	-0.0077	-0.0324	-0.0758	0.1665	0.0681	-0.0392
26 27	0.1950 0.1800	0.0478 0.0381	0.0332	0.0118	-0.0103	-0.0515	-0.0793	0.1566	0.0517	-0.0452 -0.0594
28	0.1698	0.0236	0.0051 -0.0066	-0.0163 -0.0312	-0.0482 -0.0656	-0.0721 -0.0955		0.1190	0.0279	-0.0903
29	0.1525	0.0180	-0.0000	-0.0343	-0.0828	-0.1027		0.1059	-0.0025	-0.0991
30	0.1402	0.0060	-0.0329	-0.0475	-0.1108	-0.1164		0.0990	-0.0137	
31	0.1285	-0.0180	-0.0476	-0.0584	-0.1222	-0.1201		0.0837	-0.0306	
32	0.1216	-0.0271	-0.0701	-0.0659	-0.1529	-0.1378		0.0686	-0.0394	
33	0.1139	-0.0385	-0.0747	-0.0851		-0.1500		0.0588	-0.0483	
34	0.0939	-0.0705	-0.1062	-0.0965		-0.1713		0.0437	-0.0808	
35	0.0844	-0.0783	-0.1241	-0.1117		-0.1846		0.0362	-0.0982	
36 37	0.0605 0.0508	-0.1021 -0.1103	-0.1373 -0.1500	-0.1298 -0.1540		-0.2370		0.0184	-0.1098 -0.1244	
38	0.0401	-0.1223	-0.1798	-0.1731				0.0083	-0.1458	
39	0.0172	-0.1322	-0.2007	-0.1923				-0.0138	-0.1598	
40	0.0060	-0.1637	-0.2288	-0.2152				-0.0221	-0.1691	
41	-0.0121	-0.1761						-0.0294	-0.1934	
42 {	-0.0154	- 3.1950						-0.0397	-0.2323	
43	-0.0275	-0.2147						-0.0425		
44								-0.0492		
45								-0.0650		
46								-0.0788 -0.0884		
46								-0.0954		
.,								-0.1259		
50								-0.1422		
51								~0.1520		
52								-0.1637		
53								-0.1676		
54]								-0.1872		
5								-0.2052 -0.2239		

Subtest is one of the few subtests whose second largest eigenvalue is substantially less than the first and also not so much greater than the third and other negligibly small eigenvalues, the fact which practically indicates a single common factor structure. This may be due to the fact that reading ability is always required in the performance in any subtest in addition to the content of measurement, but, unlike in the other nine subtests, in Vocabulary Subtest those two abilities are close in nature. In any case, this result is one of the reasons why Vocabulary Subtest was selected for the present study.

The factor loading matrix of the forty-three response tendencies is given as Table 5-3. We can see in this table that all the factor loadings on the first common factor are positive, and, except for those of items 24 and 44, they are greater than 0.300, ranging from 0.316 for item 39 to 0.691 for item 30. The largest cluster of factor loadings we can find in those common factors excluding those in the first one is the pair in the fourth factor, i.e., 0.393 for item 33 and 0.368 for item 44. Most of the factor loadings on those other common factors are less than 0.300 in absolute value, the fact which indicates their weak influences. From this result, a decision was made to proceed by defining operationally the first common factor as the vocabulary ability and to use the whole set of items in the Subtest as the Old Test.

The proportion correct, $p_{\bf g}$, for each item g is given in Table 5-4. In the same table, also presented are the normal deviate, $\hat{\gamma}_{\bf g}$, corresponding to the proportion correct $p_{\bf g}$, and the estimated

TABLE 5-3

Factor Loading Matrix of Forty Common Factors of the Forty-Three Item Response Tendencies of the Iowa Level 11 Vocabulary Subtest, Obtained by the Principal Factor Solution.

	•		FACTOR	FACTOR	FACIOR	FACTUR	1011	10-14			L ACTOP
			2	E.	4	s.	ş	^	r.	c	10
	72	61.	02	0.350	0.042	•	-0.230	-0.211	0.001	0.030	0.195
~	52	0.638	-0.051	-0.109	0.048	0.065	-0.175	•	-0.011	150.0-	-0.010
13	92	. 52	-0.042	-0.298	-0.077	-0.177	0.015	-0.010	-0.015	4 80°0-	450.0
<u>•</u>	27	.51	1	-0.127	0.130	-0.055	0.243	-0.041	-0.198	0.091	051-0-
-5	82	.55	-0-105	0.009	0.142	0.017	-0.147	-0.206	0.065	-0.0A	\$51.0-
و	£	• 65	-0.166	0.024	-0.074	0.145	-0.079	-0.052	-0.267	6.02	5.115
	R	£.	0.022	-0.081	-0.139	-0.097	-0.052	-0.106	-0.01A	-0.07R	050.0-
6 0	31	6.	0.094	-0.227	0.052	-0.037	-0-112	0.004	0.018	-0.015	0.00A
<u>~</u>	×	æ.	-0.273	0.004	-0.022	0.058	-0.061	0.056	-0.009	-0.076	-0.0A2
<u> </u>	33	34	-0.250	-0.054	0.393	-0.262	0.063	0.095	0.216	-9.175	1 H1. "U
=	*	.5.	-0.210	-0.003	0.171	0.029	900.0	0.001	-0.117	-0.144	7.172
112	35	4	-0.118	-0.045	-0.122	0.330	0.029	0.161	0.160	-0-154	0.016
113	36	.54	-0.283	-0.008	0.053	0.071	0.121	-0.115	-0.129	0.055	0.221
* -	37		0.035	0.017	0.094	-0.002	-0.157	0.063	190.0-	0.132	0.00A
115	8 2	S.	0.080	0.004	-0.065	-0.112	-0.082	0.197	-0.0AB	0.247	6.754
911	39	.3	0.037	-0.012	0.033	0.053	0.063	-0.144	1,50.0	4 CO. O	160.0
-11	3	₹.	0.245	-0.109	600.0-	0.092	-0.123	-0.029	0.155	0.045	0.153
13	7	4.	-0.245	0.108	-0.035	0.133	0.225	0.093	7.104	0.111	0.140
611	24	4	0.028	0.078	0.172	-0.044	-0.234	0.020	0.000	0.046	7.114
120	£ 3	55	-0.190	0.013	-0.070	900.0	-0-051	0.144	670.0	101.0	\$10°0
121	\$	Ξ.	0.257	-0.054	0.368	0.136	0.046	0.273	0.108	0.157	0.082
221	45	• 66	-0-106	-0.087	-0.068	-0.043	-0.075	-0.022	0.031	0.017	151.0-
123	9#	. 53	0.050	850.0-	-0.034	0.057	0.033	0.042	0.100	0.040	470°0-
124	47	₹.	0.021	-0.112	-0.213	600.0	0.048	-0.075	0.129	-0.191	0.734
125	\$	•	0.105	-0.195	0.011	240.0	0.021	0.027	-0.036	-0.07	0.01%
126	67	ñ	-0-133	0.011	-0.092	0.037	0.083	0.016	0.107	0.032	101-0-
121	3 3	.3	0.064	-0-111	-0.225	-0.119	0.011	0.244	-0.001	-0.07	201°
1 2 B	51	ď,	-0.784	-0.014	0.011	0.249	-0.104	0.198	-0.105	. 60.0	-0.130
129	25	.5	0.053	-0.065	0.093	-0.282	-0.003	990-0-	960.0-	0.040	-0.017
130	53	3	0.089	-0.126	-0.145	-0.072	0.103	-0.102	0.012	1.247	0,000
=======================================	J,	4	0.272	-0.040	0.129	0.014	0.055	-0.112	-0.013	-0.163	P () ()
132	22	3	0.005	-0.052	0.050	-0.012	0.025	-0.097	0.130	0.161	-0.116
133	%	5	0.161	0.048	-0.007	0.059	-0.095	-0.133	0.095	9110	4 C C C
134	23	÷.	0.265	•	560.0	0.162	-0.035	0.00A	-0.070	-0.199	790.0-
135	3 2	38	0.204	0	-0.017	7.187	0.240	-0.223	-0.025	9.00	נירר ר
136	29	4.	0.060	0.217	-0.011	-0.074	-0.127	-0.031	0.114	• 0.h	650°0-
137	8	• 56	0.052	٠١3	-0.107	-0.178	-0.010	-0.007	0000-0-	680.0	0.067
138	19	*	0.237	0.022	-0.086	-0.002	610.0-	0.129	-0.123	-0.787	-11.134
133	29	•	-0.087	٠,	150.0-	0.10	0.090	-0.026	0.137	0.023	F 20 - 0 -
C\$1	63	V.	0.062	0.225	0.004	0.01	0.120	С	-0.059	ē.	186.0-
-	3	9	0.106	۲.	-0.106	~	0.041	~	910.0-	٦.	٠. دی. د
142	65	• 51	0.189	0.110	0.060	-0.070	0.204	•	-0.103	2.0A5	٠.١١
[+]	9 9	Ÿ.	0.296	0.237	٠	2.032	00.1.0	0.110	186.0-	2	* # C * C =

TABLE 5-3 (Continued)

	!	£ & C T OB	E AC TOB	647108	640 108	E A C T OB	EACTOR	E AC TOB	6 4 7 1 10	901343	
	5	-1	12	13	51	51	91	17	81	19	202
	*	.19	•	0.014	-0.019	-0.121	-0.055	0.067	0.082	0.014	0.066
~	52	0.160	-0.217	-0.023	110.0-	0.169	0.012	010.0	0.051	+60°0-	-0.029
_	5 8	.10	•	0.047	0.057	-0.095	-0.171	-0.084	0.108	0.131	-0.125
•	23	.01	0.043	0.002	-0.130	-0-154	0.097	-0.011	-0.018	-0.036	-0.056
2	82	•0	•	0.072	-0.025	0.016	-0-129	090*0-	0.017	900.0	-0.095
•	દ્ય	90.0		0.015	0.099	-0.025	-0.179	-0.087	-0.157	0.00-0-	-0.080
1	8	.08		0.080	-0-126	0.003	0.071	0.061	-0.219	0.039	-0.092
5 0	31	0.15		0.053	+00.0-	-0.017	0.213	900.0-	-0.057	0.014	-0.018
6	32	.15	•	650-0-	0.113	0.074	-0.050	650.0-	-0.003	0.067	0.017
2	33	•02	٠.	-0.074	0.098	160.0-	0.033	-0.100	690.0-	0.021	-0.042
11	*	. 16	9	0.020	-0.009	0.326	0.040	0.142	-0.068	0.057	0.033
12	32	•10	٠.	0.127	-0.074	-0.034	-0.031	-0.072	990.0	-0.001	0.001
13	36	0.03	Ξ.	0.051	0.014	-0.065	290.0	-0.010	-0.028	0.033	0.085
•	37	.07	ö	-0.112	-0.086	-0.003	0.010	-0.145	0.029	-0.011	-0.071
15	æ	.01	_	-0.111	0.098	-0.117	-0.047	-0.068	-0.111	-0.023	0.030
16	6 6	.08	0	-0.210	-0.092	0.030	-0.035	-0.099	0.032	0.124	0.020
1.	Ş	Ξ.	٠.	0.018	090.0	-0.030	0.114	690.0-	0.066	0.010	-0.015
81	₹	·	9	150.0-	-0.106	0.131	0.013	-0.080	0.139	-0.079	-0.088
<u> </u>	42	.13	٠.	0.026	-0.129	-0.041	0.062	0.064	0.010	-0.195	-0.136
6.5	43	00.	٠.	-0.050	-0.015	-0.001	-0.068	0.022	-0.027	-0.042	0.138
17	\$	•00	0	0.137	-0.147	0.030	-0.116	0.004	-0.093	0.019	£00.3-
22	4 5	90.	7	-0.103	0.003	-0.053	0.002	0.213	0.042	-0.112	0.103
53	9	•0•	٠.	-0.103	-0.116	-0.053	-0.127	0.082	-0.097	-0.120	0.103
9 7	47	-19		0.003	0.029	-0.136	0.035	0.013	-0.060	-0.092	-0.029
52	\$.07	٩.	-0.066	0.039	-0.087	-0.030	951.0	0.137	-0.130	0.011
5 9	6	. 26	٠.	-0.084	-0.048	660*0-	102.0	-0.113	-0.050	-0.044	0.048
21	ጽ	•01	۰.	0.068	-0.105	0.053	-0-147	0.083	0.035	0.000	0.023
87	51	• 15	٥.	0.151	0.153	160.0-	0.151	0.051	0.102	0.188	0.047
62	25	•02	Ξ.	0.082	-0.143	-0.033	-0.001	-0.030	0.241	0.082	0.222
30	£	.03	Ξ.	0.000	0.092	0.219	0.009	-0.190	-0.116	-0.054	0.142
31	¥	•05	۰.	-0.025	0.122	0.107	-0.055	-0.114	0.068	-0.143	0.142
32	22	0.05	़	0.055	0.143	0.103	-0.016	691.0	-0.031	0.015	-0.104
£ ;	92	90.0	0	-0.226	0.069	0.015	9,0.0	0.016	0.008	0.215	-0.045
34	27	•05	-	-0.097	-0.113	-0.068	-0.066	-0.019	-0.150	0.124	0.109
35	28	90.0	۰.	0.028	-0-144	-0.040	0.051	0.043	0.014	0.028	-0.049
ş	29	<u>-</u>	∹	0.305	-0.062	-0.026	0.037	-0.151	-0.027	-0.067	0.041
37	8	0.03	۰.	0.107	-0.073	0.049	910.0	-0.021	0.048	0.055	-0.104
38	61	=	٣.	-0.151	0.017	0.111	0.020	-0.077	0.123	•06	-0-177
39	29	•00	়	-0.053	-0.017	-0.039	-0.163	0.044	0.005	0.018	-0.008
3	63	• 05	∹	-0.005	-0.082	-0.014	-0.010	-0.045	-0.029	0.059	180.0-
7	7		∹	•	-0.064	0.111	0.169	0.085	-0.055	•05	0.010
7	9	0.	٥.	0.175	0.159	-0.030	-0.060	0.145	0.004	0.021	-0.764
43	99	•05	٠.	0.005	0.242	-0.075	0.034	-0.020	0.011	•	0.026

TABLE 5-3 (Continued)

	it es	FACTOR	FACTOR	FACTOR	FACTOR	FACTOR		FACTOR	FALTOR	FACTOR	FACTOR
		21	22	53	54	25	56	2.1	2.8	50	٥٤
=	7 2	C	-0.022	.03	.08	-0.025	.10	-0.023	0	Ξ.	190.0-
12	%	ċ	0.027		0.	0.137	0.053	-0.078	10.	0.038	0.042
2	%		0.001	-0.086	.05	0.037	0.007	-0.085	0.	٠ij٠	0.100
<u>*</u>	27	ċ	0.034	-0.094	.10	0.058	-0.036	-0.087	• 04	-0.054	100.0-
- 2	8 2 9		-0.056	0.050	0.038	100.0	-0.007	0.147	-0.122	.02	•
9	2	ດ່	-0.056	-0.045	-0.020	0.034	-0.112	0.044	.01	. 14	110.0
<u>~</u>	8		0.011	0.040	-0.051	O	0.133	-0.057	£C.		-0.097
<u> </u>			-0.148	-0.011	-0.042	-0.040	-0.016	0.111	600.0-	.05	A 0 0 A
<u>-</u>	2		0.023	0.104	-0.012	-0.036	0.103	-0-139	900.0-	90.	U26.0-
C .	:		-0.037	0.028	-0.015	0.041	0.024	0.027	9,000	0.027	960-0-
111	*		-0.021	-0.045	0.119	-0.011	-0.091	0.088	+00°0-	č	•
211	32		0.007	0.074	0.043	+90.0-	-0.008	-0.008	0.032	٥٠.	080.0-
113	8	ċ	0.094	0.080	-0.061	0	-0.030	-0.018	150.0	.03	580.0
114	37		0.067	0.126	0.134	-0.164	-0.002	-0.067	-0.041	.03	0.107
115	8 2		-0.087	-0.027	0.079	ö	-0.006	0.021	0.014	10.	910-0-
116	8		0.180	-0.014	-0.077	-0.050	0.054	0.089	-0.093	.12	r.004
111	Q		0.072	-0.020	0.192	0.010	-0.038	0.056	0	£ ;	-0.032
118	7		-0.152	-0.080	0.009	0.012	0.069	-0.019	0	ç.	-0.92B
611	42		0.029	-0-014	-0.169	-0.010	0.051	0.029	٥,	<u>ر</u> ۲	0.015
12)	-		0.184	-0.011	-0.060	0.095	-0.059	0.005	-0.022	=	190.0
121	3		100.0	0.077	-0.052	0.040	-0.018	-0.066	<u>-</u>	• 04	£10.0-
122	4 2		-0.065	0.160	0.081	900.0	-0.016	-0.054	0.114	•	0.019
123	9 !		900.0	0.001	0.038	0.019	-0.077	0.020	.12	.05	-0.032
\$21	14		0.060	0.049	-0.083	-0.045	-0.110	-0.020	• 0	· 05	M 2 0 . 0 -
125	8 9		0.026	-0.130	0.015	0.044	160.0	0.068	-0.045	• 00	0.012
126	6		-0.068	0.010	0.027	0.044	0.080	0.087	100.0-	.01	0.069
121	8		-0.053	0.109	-0.007	0.036	0.068	0.105	-0.018	00.	0.059
128	51		-0.001	-0.011	-0.108	-0.052	0.008	0.013	-0.037	•	210.0-
153	25		0.010	0.033	-0.080	-0.064	-0.077	0.013	990.0	٠05	mc0.0-
130	. .		_	-0.002	-0.047	0.013	0.111	0.028	0.051	•	-0.049
131	3 1		~	-0.037	-0.005	980-0-	600.0-	-0.076	-0.035	.05	0.051
132	n (<u> </u>	-0.115	-0.007	-0.039	္	-0.029	0.032	•	0.0
133	ያነ		~	0.085	-0.081	0.165	Ξ.	-0.058	-0.034	0.01	-0.046
136	2		=	-0.162	0.025	0.037	0.115	-0.050	0.148	.02	-0.001
135	2		*	0.065	-0.018	0.044	<u>-</u>	-0.023	-0.004	03	0.070
135	29		2	-0.076	0.001	0.073	•	-0.082	•04	٠.	0.050
137	3 8		으.	0.020	0.081	0.177	. 25	0.028	0.	α.	L40.0-
38	19		=	-0.026	• 08	-0.059	.01	0.001	٠. ن ع	• 05	(NA)
133	29		~	-0.076	=	-0.062	0	0.003	20.		120.0
0 7 1	63		8	0.034	0.032	-0.078	-0.452	0.111	0.182	ç	い。 うそう
~ ·	3 :	-2.065	0.008	-0.069	0.046	~ . 1	• 0	-0.0AL	٠٥٨	Œ	750.0
2 4 1	2 (5	0.059	0.058	-0.058	0.050	-0.005	£ 20°0-	-0.075	110.0
-	£		=	0.120	5	ဌ	٦,	•	c	ć	10.0-

TABLE 5-3 (Continued)

FACTOR 40	100.0-	0.013	100.0	+10.0-	-0.013	00000	0.021	-0.011	-0-013	0.019	-0.010	0.014	0.019	-0.017	-0.001	-0.003	0.010	-0.004	-0.004	0.094	-0.010	-0.007	0.028	-0.032	-0°05	0.003	-0.03	0.005	-0.001	-0.008	0.014	-0.00R	0.004	-0.011	-0.003	-0.002	0.002	0.012	-0.010	0.010	100.0-	0.014	-0.01B
FACTOR 39	0.014	٠	0.037	-0.008	0.010	-0.022	-0.013	0.034	-0.026	-0.011	0.005	0.032	-0.019	-0.010	0.007	0.027	-0.038	0.002	-0.003	0.028	0.007	0.019	0.001	0.010	-0.028	0.007	-0.046	-0.011	-0.005	0.011	-0.021	-0.017	-0.005	900.0	-0.021	-0.00A	-0.003	0.012	9	80		ð	8
FACTOR 38	0.025	00.	+10*0-	0.013	-0.034	-0.025	-0.004	0.067	0.050	-0.042	0.011	-0.002	940.0	-0.058	0.061	0.044	-0.020	-0.010	-0.041	-0.023	0.036	-0.011	-0.012	-0.012	0.015	900.0	0.002	-0.044	-0.014	-0.059	0.028	0.013	-0.010	-0.027	-0.021	0.032	.02	910.0	00.	0.014	40.	-0.027	00.
FACTOR 37	0.024	-0.025	0.039	0.043	-0.031	0.017	-0.017	-0.026	0.055	-0.037	0.026	0.018	-0.035	-0.038	-0.043	0.004	0.039	-0.047	0.069	-0.002	0.019	-0.026	0.001	-0.017	-0.017	0.102	0.036	-0.038	0.022	900.0	0.001	0.012	0.035	-0.025	-0.037	-0.002	-0.074	0.003	-0.014	0.011	-0.000	0.034	-0.00-
FACTOR 36	-0.035	0.050	-0.039	0.049	0.019	0.019	-0.024	140.0-	-0.085	-0.010	-0.016	0.084	0.017	0.023	0.035	0.012	-0.043	-0.055	0.005	-0.021	-0.010	110.0-	690*0-	-0.001	010.0-	0.051	0.039	-0.003	-0.001	-0.024	0.067	0.052	0.020	0.011	-0.032	-0.033	0.052	-0.024	0.038	-0.050	610.0	0.014	-0.023
FACTOR 35	-0.026	•	•		0.112	•	0.019	-0.065	0.021	-0.005	-0.027	-0.044	0.041	-0.035	0.029	-0.024	0.007	010.0	-0.015	190.0	0.047	0.003	-0.102	0.051	0.082	0.015	100.0	-0.009	-0.046	-0.005	0.026	-0.050	0.035	-0.012	-0.022	0.017	-0.032	0.021	-0.055	0.062	•	0.046	•
FACTOR 34	900.0	-0.054	0.072	-0.073	010.0	-0.008	-0.013	-0.052	0.019	0.011	0.057	0.010	0.017	-0.021	990.0	-0.034	-0.035	-0.087	0.039	-0.032	0.031	0.013	-0-031	-0.049	0.074	0.035	-0.084	-0.019	0.011	0.049	-0.036	900.0-	•	-0.044	0.119			0.028		•	0.046	•	8
FACTOR 33	0.072	Ξ	٠ و	• 02	-0.043	0.049	0.064	0.038	-0.025	0.039	•	0.032	-0.097	-0.016	-0.008	0.010	-0.040	0.019	0.014	0.130	-0.003	0.068	-0.087	-0.036	9	3	0.031	0.009	-0.018	•	0.123	0.013	0.020	-0.043	0.067	-0.034	0.034	5	0	02	-0.035	9	8
FACTOR 32	-0.005		•						-0.066	-0.001	0.030	0.001	-0.019	-0.008	0.028	0.034	0.127	-0.018	-0.046	0.082	0.015	910.0	-0.115	-0.055	-0.017	-0.032	0.002	-0.033	+00.0-	-0.021	-0.050	-0.059	-0.030	-0.040	0.031	0.023	-0.124	0.010	0.1.0	-0.050	-0.025	-0.012	090.0
FACTOR 31	3.055	0.011	990.0	0.057	0.098	-0.07	\mathbf{c}	0	-0.043	0	0	0	0.092	-0.076	0.085	-0 -03	0.00	20°C	1.01	-0.036	•	0.013	0.023	-0.034	-0.123	-0.073	0.101	0.003	-0.056	0.030	0.00	0.059	210.0-	0.010	0.030	ŝ	٩.	٩.	٩	٠,	0.065	۰.	•
	*	\$2	9 2	27	æ	బ	8	3	2	33	, The	35	%	37	緊	39	\$	7	2	4 3	3	45	\$	-	\$	Ş	S	5	25	53	3	25	፠	27	3	20	8	61	8	63	Z	6	8

TABLE 5-4

Estimated Item Discrimination Parameter \widehat{a}_g And Item Difficulty Parameter \widehat{b}_g , Proportion Correct p_g And Normal Deviate $\widehat{\gamma}_g$, for Each of the Forty-Three Old Test Items of the Iowa Level 11 Vocabulary Subtest.

Item g	Discrimination Parameter ag	Difficulty Parameter B _g	Proportion Correct Pg	Normal Deviate Yg
24	0.106	-4.257	0.70115	0.01740
24 25	0.196 0.829	-1.000	0.79315 0.73816	-0.81740 -0.63768
26	0.614	-0.821	0.66624	-0.42955
27	0.594	-0.340	0.56895	-0.17370
28	0.669	-0.900	0.69162	-0.50045
29	0.867	-1.077	0.75973	-0.70543
30	0.956	-0.557	0.64975	-0.38465
31	0.938	-0.179	0.54865	-0.12225
32	0.940	-0.803	0.70897	-0.55038
33	0.434	-2.331	0.82318	-0.92755
34	0.598	-1.210	0.73266	-0.62088
35	0.489	-0.569	0.59856	-0.24962
36	0.657	-0.987	0.70601	-0.54177
37	0.351	0.577	0.42428	0.19096
38	0.665	-0.468	0.60237	-0.25949
39	0.333	-0.676	0.58460	-0.21368
40	0.683	0.402	0.41032	0.22672
41	0.531	-0.948	0.67174	-0.44472
4	0.436	0.258	0.45897	0.10303
43	0.672	-0.867	0.68570	-0.48370
44	0.143	4.175	0.27665	0.59282
45	0.898	-0.357	0.59433	-0.23870
46	0.612	-0.318	0.56599	-0.16617
47	0.494	-0.781	0.63536	-0.34608
48	0.849	0.054	0.48604	0.03500
49	0.421	-0.626	0.59602	-0.24306
50	0.346	-0.250	0.53257	-0.08173
51	0.664	-0.420	G.59179	-0.23215
52	0.640	0.217	0.45347	0.11690
53	0.402	0.526	0.42217	0.19635
54	0.573	0.126	0.47504	0.06261
55.	0.667	-0.342	0.57530	-0.18988
56	0.593	1.007	0.30372	0.51373
57	0.370	0.398	0.44501	0.13828
58	0.416	0.782	0.38198	0.30028
59	0.491	-0.731	0.62648	-0.32254
60	0.678	-0.170	0.53807	-0.09557
61	0.519	0.748	0.36506	0.34497
62	0.938	-0.485	0.62986	-0.33148
63 64	0.637	-0.398	0.58460	-0.21368 -0.02652
65	0.818 0.606	-0.042 0.595	0.51058 0.37902	0.30806
66	0.604	-0.376	0.37902	-0.19420

item discrimination parameter, \hat{a}_g , and item difficulty parameter, \hat{b}_g , which are given by

(5.1)
$$\hat{a}_g = \rho_g (1 - \rho_g^2)^{-1/2}$$

and

(5.2)
$$\hat{b}_g = \hat{\gamma}_g \rho_g^{-1}$$
,

where ρ_g is the factor loading of item g on the first common factor. Those values thus calculated will serve as the estimated item parameters in the normal ogive model on the dichotomous response level, whose item characteristic function is given by (4.1), for each Old Test item.

VI. Test Information Function of the Old Test and the Transformation of the Latent Trait θ to τ

The test information function, $I(\theta)$, of the Old Test is given by the sum total of the item information function, $I_g(\theta)$, which can be written as

(6.1)
$$I_g(\theta) = \left[\frac{\partial}{\partial \theta} P_g(\theta)\right]^2 \left[P_g(\theta)Q_g(\theta)\right]^{-1}$$
,

where $P_{g}(\theta)$ is the item characteristic function given by (4.1) and

(6.2)
$$Q_{g}(\theta) = 1 - P_{g}(\theta)$$

Thus we can write

(6.3)
$$I(\theta) = \sum_{g=1}^{n} I_g(\theta)$$

It has been pointed out (Samejima, RR-80-2, Final Report) that the square root of the test information function, rather than the test information function itself, is a useful function in many ways. Among others, it can be used in the process of transforming the original latent trait to another, which has a constant amount of test information for the range of ability of interest, as we have seen in Section 3.

Figure 6-1 presents the square root of the test information function of the Old Test by a solid line. We can see in this figure that our Old Test is most informative around $\theta = -0.4$, i.e., a little below the average ability level of our subjects. This is expected from the fact that thirty test items out of the total of forty-three have negative difficulty parameters, and twenty-eight test items have their difficulty parameters between -1.0 and 0.2, as is observed in Table 5-4. In the same figure, also presented by a dotted line is the polynomial of degree 7 obtained by the method of moments, using the interval of θ , (-5.0, 5.0). The actual formula of this polynomial is given by

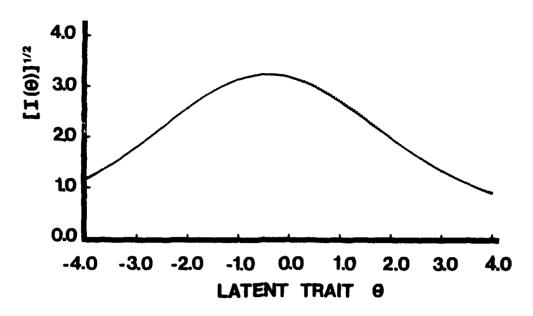


FIGURE 6-1

Square Root of Test Information Function $[I(\theta)]^{1/2}$ of the Level 11 Vocabulary Subtest (Solid Line) And Its Approximation by the Polynomial of Degree 7 Obtained by the Method of Moments with the Interval of θ , [-5.0, 5.0] (Dotted Line).

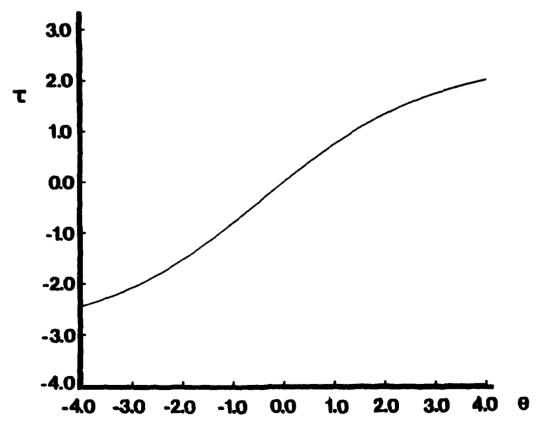


FIGURE 6-2

Polynomial Transformation of θ to τ .

(6.4) $[I(\theta)]^{1/2} \doteq 3.1915950 - 0.23604972\theta - 0.27322550\theta^{2}$ $+ 0.026248259\theta^{3} + 0.012315578\theta^{4} - 0.0011485951\theta^{5}$ $- 0.00022787645\theta^{6} + 0.000018322697\theta^{7} .$

We can see in Figure 6-1 that this polynomial and the actual square root of the test information function are almost identical with each other for the interval of θ , (-4.0, 4.0) . This proves that the polynomial given by (6.4) makes a good substitute for the square root of the test information function, the result which is expected from the fact that the polynomial obtained by the method of moments is also the least squares solution for the specified degree of polynomial and interval of θ (Samejima and Livingston, RR-79-2). Actually, the method of moments was tried with four different intervals of $\ \boldsymbol{\theta}$, i.e., (-4.0, 4.0), (-4.5, 4.5), (-5.0, 5.0) and (-5.5, 5.5), and the above result showed the best fit. Those coefficients, $\sigma_{\mathbf{p}}$ $(k=0,1,2,\ldots,7)$, of the polynomials of degree 7 obtained by using the four different intervals of θ are shown in Appendix as Table A-1, together with the coefficients of the polynomials of degrees 3, 4, 5 and 6 obtained similarly by using those four intervals of θ , respectively. In this table, also presented are the original and revised coefficients, which mean those obtained by adjusting the area under the curve of $[I(\theta)]^{1/2}$ for the specified interval of θ to unity, with the midpoint of the interval and real origin of the scale as the origin, respectively. The revised coefficients were further modified to the "corrected" coefficients by readjusting the area

under the curve of $\left[I(\theta)\right]^{1/2}$ for the specified interval of θ to its real value.

The polynomial for transforming θ to τ was obtained by (3.3) and (3.4), using the coefficients, α_k (k=0,1,2,...,7), in (6.4) and setting the two constants, $C_0 = 0.0$ and $C_1 = 4.0$. The resulting polynomial of degree 8 is given by

(6.5)
$$\tau(\theta) = 0.00000000 + 0.79789874_{-}\theta - 0.029506215_{\theta}^{2} - 0.022768792_{\theta}^{3}$$

+ $0.0016405162_{\theta}^{4} + 0.00061577891_{\theta}^{5}$
- $0.000047858127_{\theta}^{6} - 0.0000081384446_{\theta}^{7} + 0.00000057258428_{\theta}^{8}$.

Figure 6-2 presents this polynomial of degree 8 for transforming $\;\theta\;$ to $\;\tau\;$.

We can write for the square root of the test information function, $I^*(\tau)$, for the transformed latent trait τ

(6.6)
$$[I*(\tau)]^{1/2} = [I(\theta)]^{1/2} \frac{d\theta}{d\tau}$$
.

Figure 6-3 presents the square root of the test information function of τ thus obtained by using the approximated polynomial for $[I(\theta)]^{1/2}$ given by (6.4), and the derivative of τ obtainable from (6.5). Since the interval of θ , (-4.0, 4.0), corresponds to the interval of τ , (-2.44244, 2.02098), as we can see in Figure 6-2, the latter interval is shown by arrows in Figure 6-3. We can see that for this interval of τ the approximated square root of the test

D

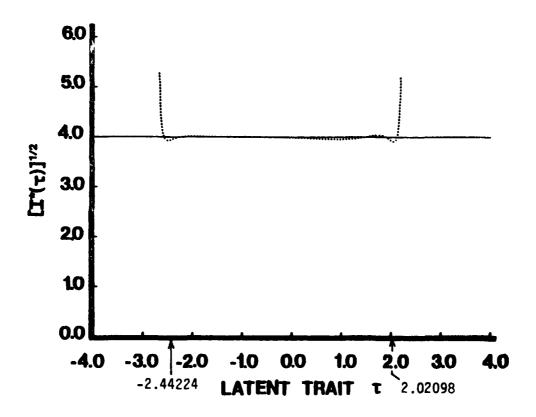


FIGURE 6-3

Square Root of Test Information Function $[I^*(\tau)]^{1/2}$ of the Level 11 Vocabulary Subtest Obtained from the Polynomial Transformation of θ to τ (Dotted Line) And Its Target (Solid Line).

information function, $\left[I(\tau)\right]^{1/2}$, is almost constant, i.e., very close to 4.0 .

The maximum likelihood estimate of θ was obtained for each individual subject from his response pattern on the Old Test items. Let $\hat{\theta}_S$ denote this maximum likelihood estimate of ability θ for subject s. This maximum likelihood estimate, $\hat{\theta}_S$, can directly be transformed to the maximum likelihood estimate of the transformed ability τ , which is denoted by $\hat{\tau}_S$, through (6.5). This was done for the 2,356 subjects, whose $\hat{\theta}_S$'s are within the interval, (-3.75, 3.75). On this stage, eight subjects were excluded from our data, since three of them obtained positive infinity for $\hat{\theta}_S$, three obtained 5.94848, 4.92496 and 4.37878, respectively, and two obtained 3.89343. They were excluded permanently from the rest of the research.

Figure 6-4 presents the frequency distribution of the 2,356 $\hat{\tau}_s$, with the interval width of 0.25. In the same figure, also presented by dotted and dashed lines are the polynomials of degree 3 and 4, respectively, which were obtained by the method of moments. In these two cases, the interval of $\hat{\tau}$ is (-1.91742, 1.95366), taking the lowest and the highest values of $\hat{\tau}_s$ among the 2,356 as its two endpoints. These two polynomials of degrees 3 and 4 are given by

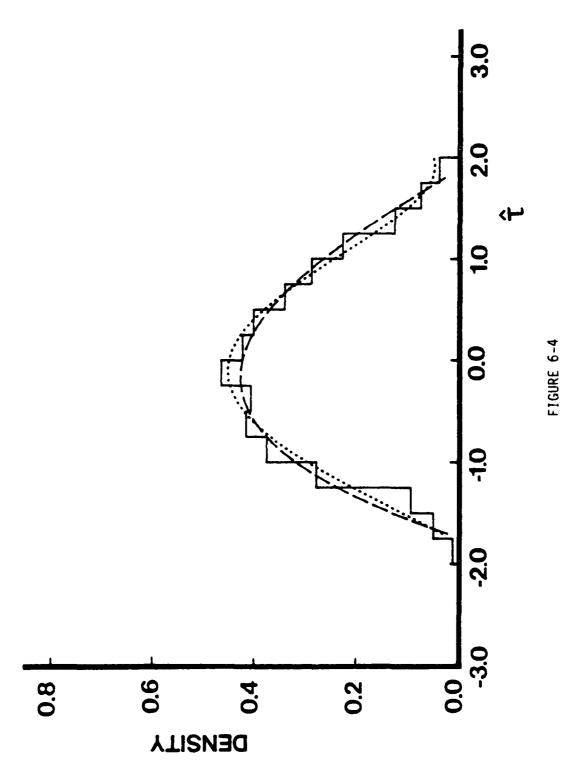
(6.7)
$$\hat{g}*(\hat{\tau}) = 0.42358084 - 0.046813019\hat{\tau}$$

- 0.13270786 $\hat{\tau}^2$ + 0.020014202 $\hat{\tau}^3$

and

٤.

Ø



Frequency Distribution of the 2,356 $\hat{\tau}_{\text{S}}$ Based upon the Old Test (Histogram), And the Two Polynomials of Degree 3 (Dashed Line) And of Degree 4 (Dotted Line) Obtained by the Method of Moments.

and

(6.8)
$$\hat{g}^*(\hat{\tau}) = 0.45023559 - 0.044232853\hat{\tau} - 0.20387563\hat{\tau}^2 + 0.018406862\hat{\tau}^3 + 0.022176405\hat{\tau}^4$$

respectively. We can see in Figure 6-4 that these two polynomials fit the frequency distribution very well. Hereafter, we shall call the situations in which (6.7) and (6.8) are adopted as the estimated density function, $\hat{g}^*(\hat{\tau})$, Degree 3 Case and Degree 4 Case, respectively.

VII. Estimated Plausibility Functions of the Distractors

Using the polynomials introduced in the preceeding section as the estimated density, $\hat{g}^*(\hat{\tau})$, the first through fourth conditional moments of τ , given $\hat{\tau}_s$, were obtained for each individual $\hat{\tau}_s$, by the formulae (3.5) through (3.8). From those results, the two coefficients β_1 and β_2 and Pearson's criterion κ were also computed by formulae (3.9), (3.10) and (3.11). They are all presented in Appendix as Tables A-2 and A-3 for Degree 3 and 4 Cases, respectively.

Table 7-1 presents the frequency distribution of the 2,356 $\hat{\tau}_S$'s with respect to the types of the conditional distribution of τ , given $\hat{\tau}_S$, in both Degree 3 and 4 Cases. These types, 1 through 7, are Pearson's Types (Elderton and Johnson, 1969; Johnson and Kotz, 1970) assigned by evaluating the values of the criterion κ . We can see in this table that in both Degree 3 and 4 Cases more than sixty

TABLE 7-1 Frequency Distribution of the 2,356 $\hat{\tau}_S$ with Respect to Their Pearson Types for the Conditional Distributions of τ .

r	,	
Туре	Degree 3 Case	Degree 4 Case
1	362	380
2	402	220
3	0	0
4	6	69
5	0	1
6	1	8
7	0	89
normal	1,458	1,536
und. 1	112	47
und. 2	15	6
Total	2,356	2,356

und. 1 : Undefined Due to Negative Even Conditional Moment(s).

und. 2 : Undefined Due to Negative P.D.F.

percent of the cases belong to the normal distribution, while most of the others belong to the Beta distribution, i.e., either Pearson's Type 1 or 2. There are some cases whose conditional distributions of are undefined, either due to negative estimated even conditional moments or to negative estimated conditional probability densities.

Those subjects have to be excluded from the rest of the research.

The above result justifies our choice of Normal Approach Method in both Degree 3 and 4 Cases. A close examination of Tables A-2 and A-3 in Appendix further discloses the fact that, in most cases where the conditional distributions of τ belong to other types of Pearson's distributions than normality the values of β_2 are very close to 3.000 , the number which characterizes the normal distribution.

Since these two sets of results are very similar to each other, hereafter we deal solely with Degree 4 Case. It is worth noting, however, that the results of Degree 3 Case would be just as respectable as those of Degree 4 Case, in spite of the fact that the degree of the polynomial approximating $g^*(\tau)$ is one less and as small as 3. A slight disadvantage of Degree 3 Case appears in the number of subjects to be discarded because of the result shown in Table 7-1, i.e., 127 compared with 53 in Degree 4 Case.

Before proceeding further, we notice that a simple, straightforward estimation of the plausibility functions of the distractors can be made by taking the frequency ratios of the subgroups of examinees who selected the separate alternative answers,

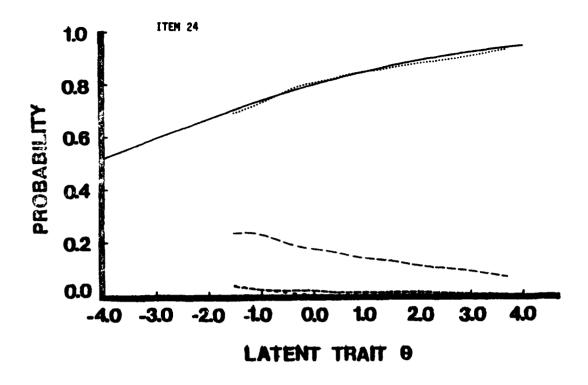
which are calculated for some appropriately set subintervals of $\hat{\theta}$. This was done by using thirty subintervals of $\hat{\theta}$ with unequal widths to make the total numbers of subjects in the separate subintervals of approximately equal, i.e., 78 or 79. The results are shown in Appendix as Figure A-1, together with the item characteristic functions in the normal ogive model, whose discrimination and difficulty parameters are shown in Table 5-4 as \hat{a}_g and \hat{b}_g . In those graphs, the frequency ratios of the correct answers, A ,are represented by dots, and those of the distractors, B , C and D , are represented by dashes of three increasing lengths.* We can see from those graphs that the set of frequency ratios for the correct answer matches the corresponding normal ogive curve well in most cases.

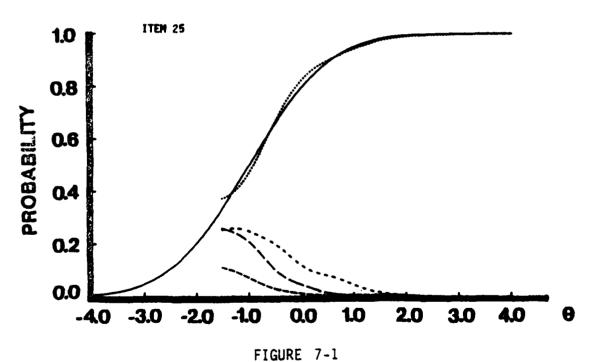
The operating characteristics of the four alternative answers were obtained for each of the forty-three vocabulary test items using the Simple Sum Procedure of the Conditional P.D.F. Approach combined with the Normal Approach Method, which were introduced in Section 3.

^{*} Because of the confidentiality of the Tests, we need to disguise the correct answer for each item from the reader. For this reason, the alternative answers, 1, 2, 3 and 4, were randomized, so that we shall always call the correct answer the alternative A, and the three incorrect answers B, C and D, throughout the rest of the present paper.

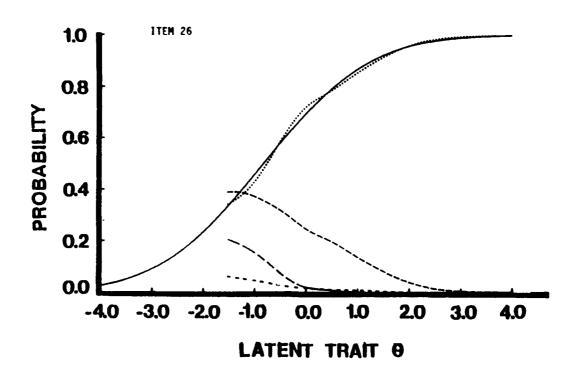
The resultant estimated operating characteristics are shown in Figure 7-1 by dotted and dashed lines, together with the normal ogive curve specified by the two estimated item parameters shown in Table 5-4, which is drawn by a solid line.

These results provide us with a variety of information. First of all, most of the nonparametrically estimated item characteristic functions are very close to the corresponding normal ogive curves, which are parametrically estimated item characteristic functions following the normal ogive model. Exceptions are the one for item 44 and, to a lesser extent, those for items 39 and 49. Secondly, most of the sets of estimated plausibility functions of distractors indicate that they belong to the Informative Distractor Model rather than the Equivalent Distractor Model, which means each separate distractor provides us with its own information. The closest configuration of the estimated plausibility functions to the Equivalent Distractor Model may be the one for item 63. There are pairs of distractors which show almost identical estimated plausibility functions with each other in certain items, however. We can see them in the alternatives B and C of item 24, B and C of item 29, C and D of item 30, B and D of item 49, B and C of item 50, C and D of item 52, B and C of item 53, B and D of item 60, C and D of item 61 and C and D of item 64. Thirdly, there are certain distractors which attract the examinees strongly for certain specific ranges of ability. Table 7-2 presents those distractors under the label, "informative" .





Estimated Item Characteristic Function Following the Normal Ogive Model (Solid Line) And the Estimated Operating Characteristics of the Four Alternative Answers Using the Simple Sum Procedure of the Conditional P.D.F. Approach Combined with the Normal Approach Method, for Each of the Forty Three Level 11 Vocabulary Items. The Length of Dashes Is Shortest for Alternative A, Next Shortest for B, Longer for C, and Longest for D.



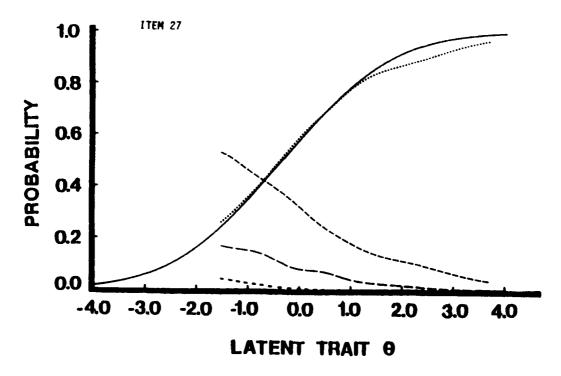
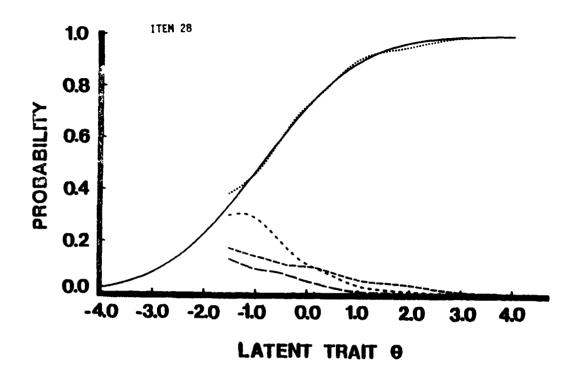


FIGURE 7-1 (Continued)

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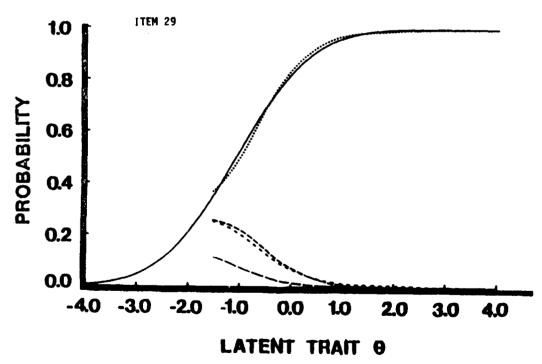
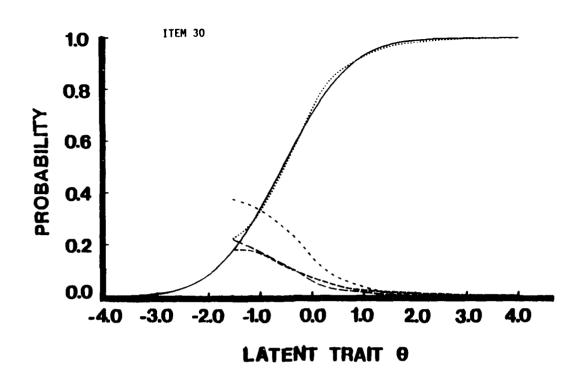


FIGURE 7-1 (Continued)



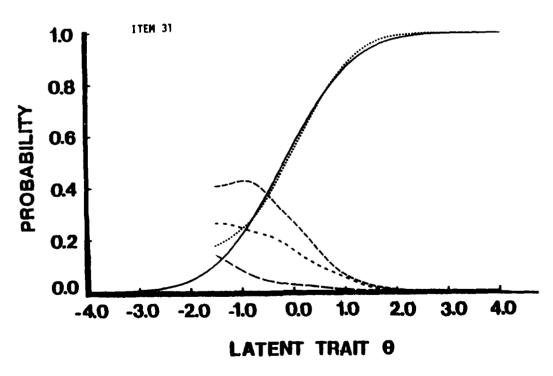
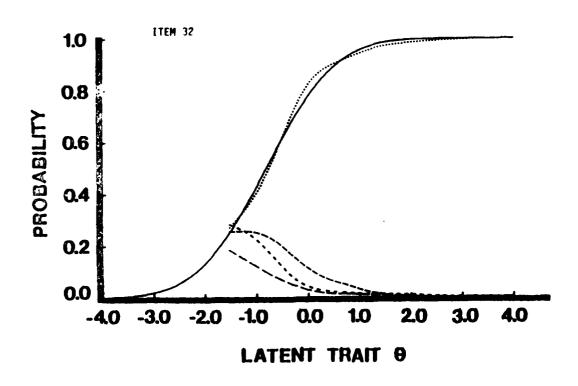


FIGURE 7-1 (Continued)

Q



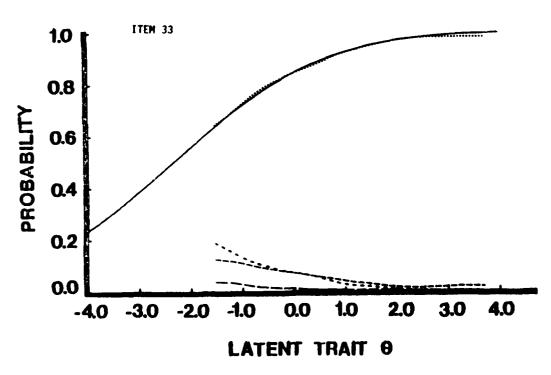
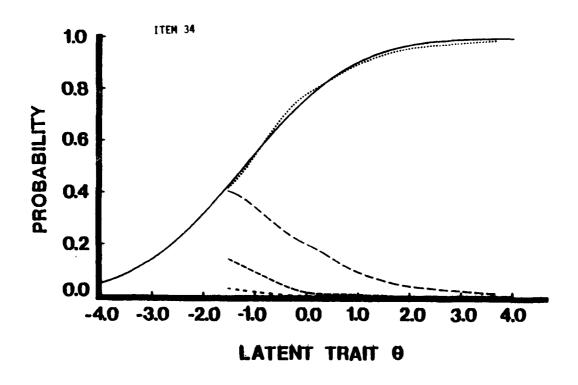


FIGURE 7-1 (Continued)



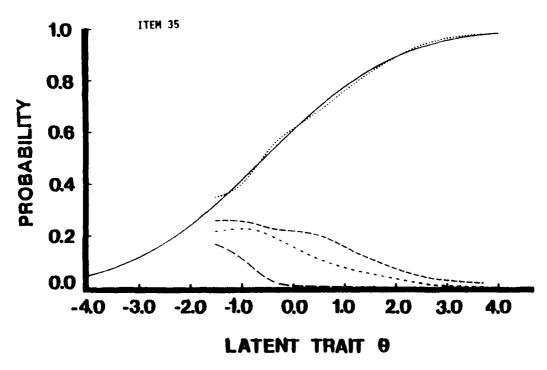
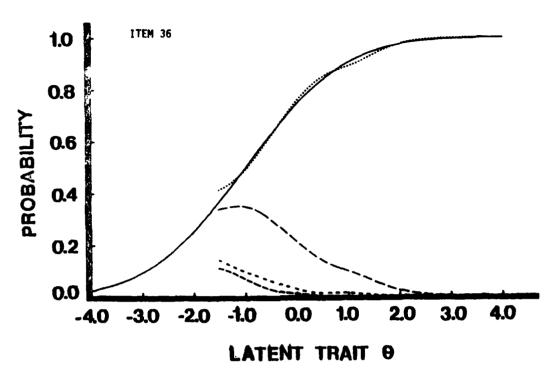


FIGURE 7-1 (Continued)

K



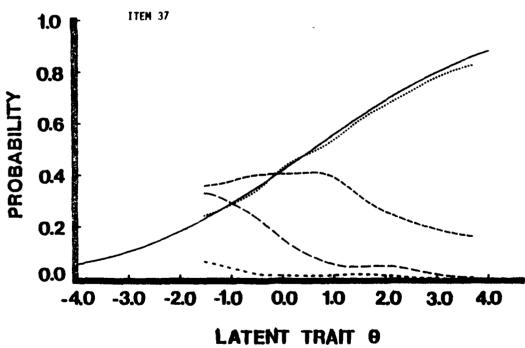
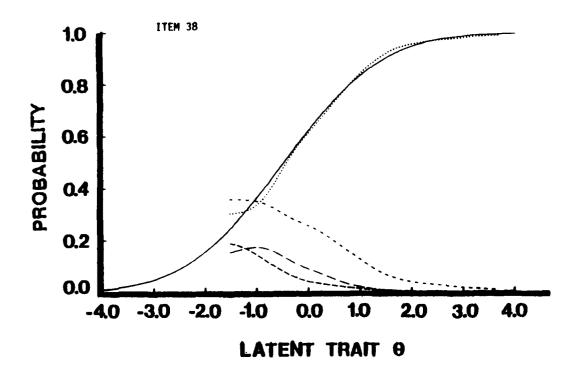


FIGURE 7-1 (Continued)



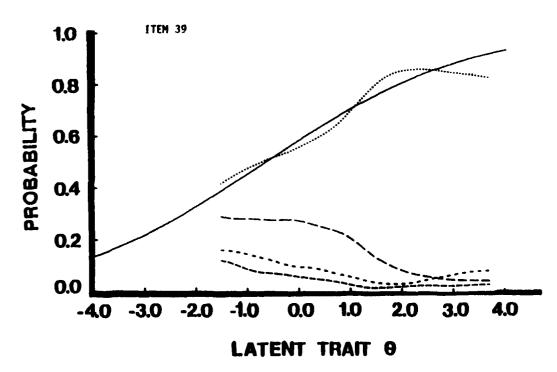
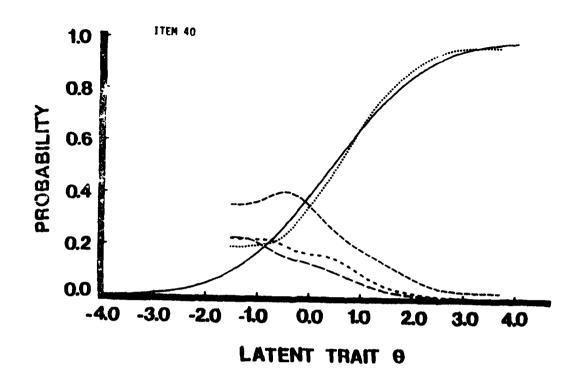


FIGURE 7-1 (Continued)



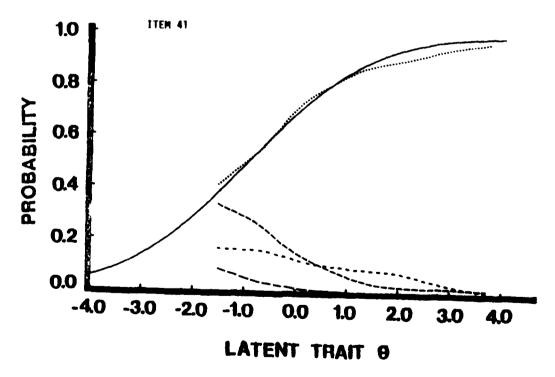
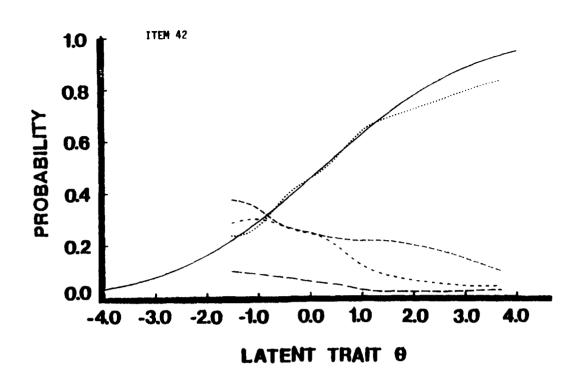


FIGURE 7-1 (Continued)



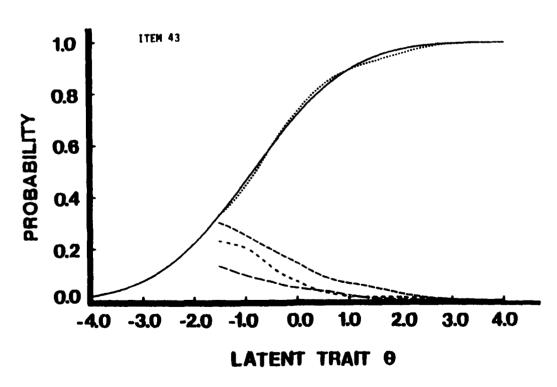
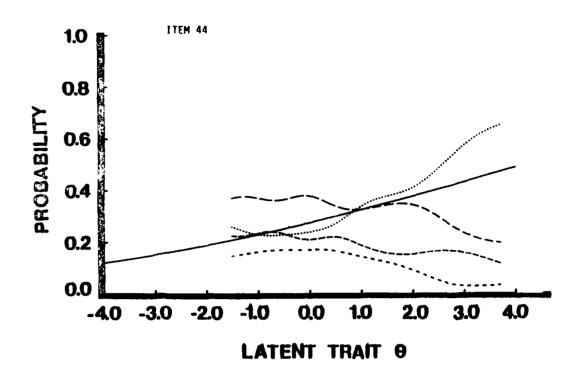


FIGURE 7-1 (Continued)



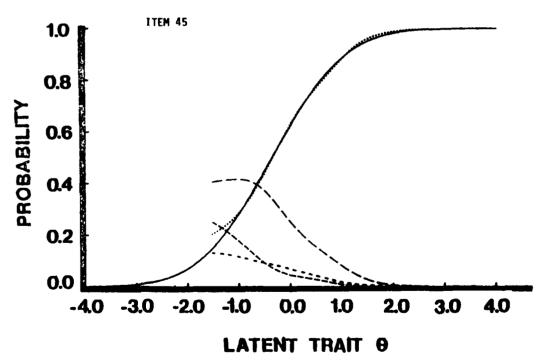
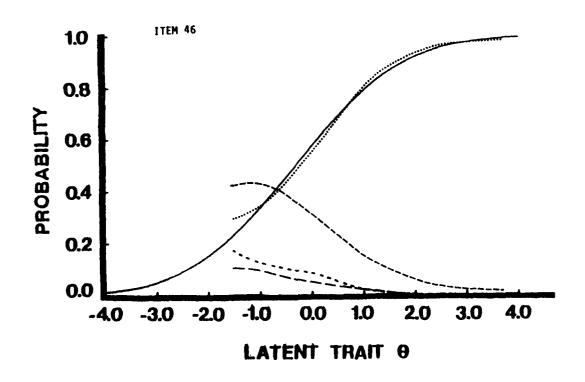


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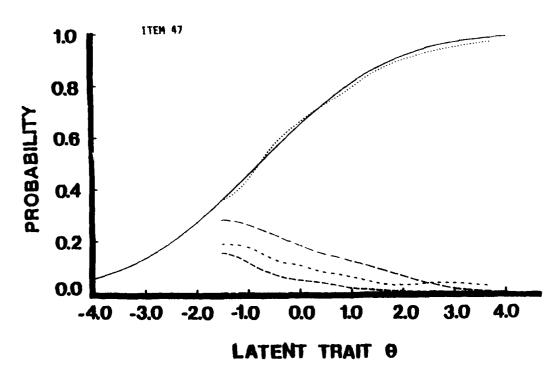
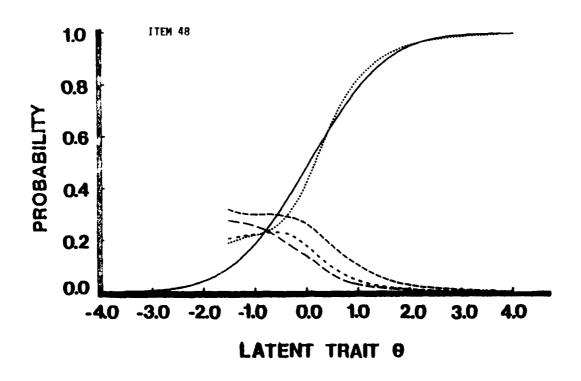


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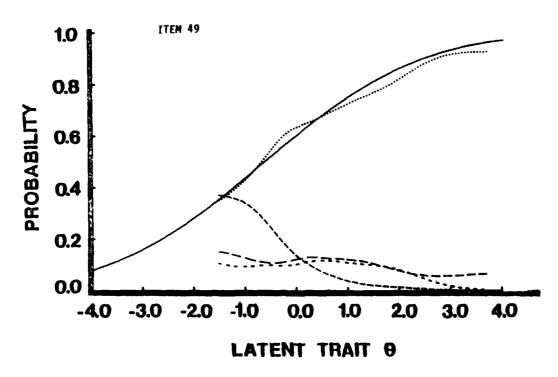
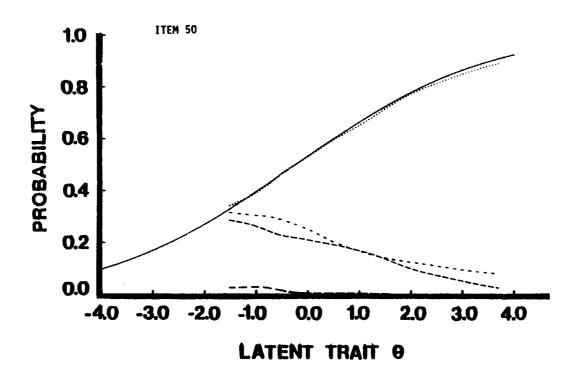


FIGURE 7-1 (Continued)



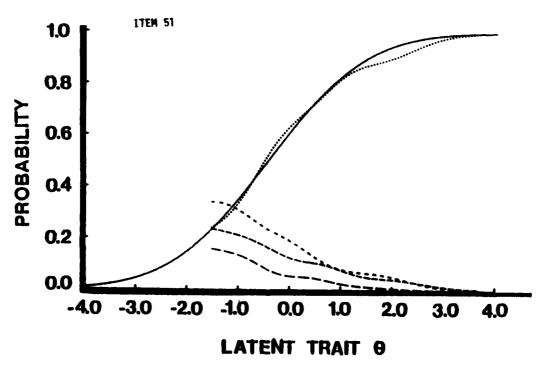
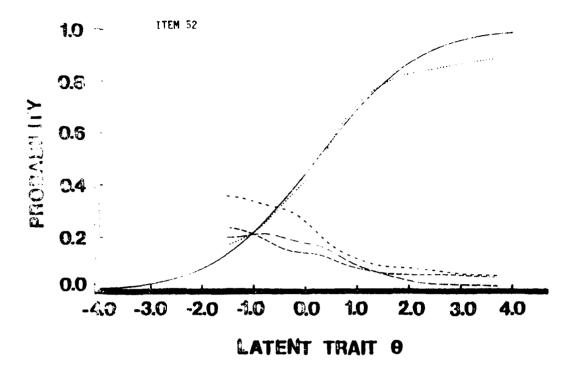


FIGURE 7-1 (Continued)



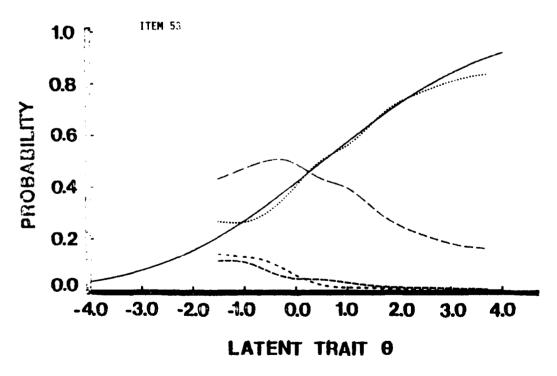
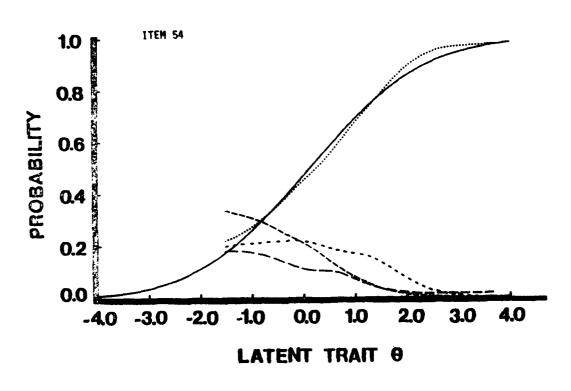


FIGURE 7-1 (Continued)



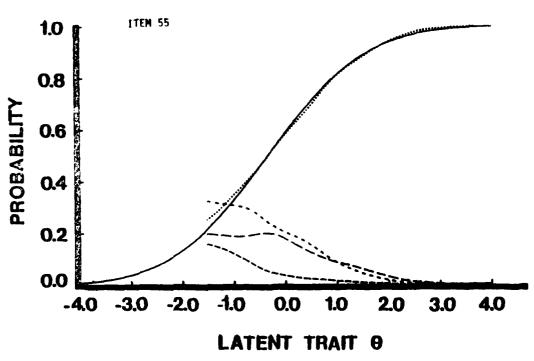
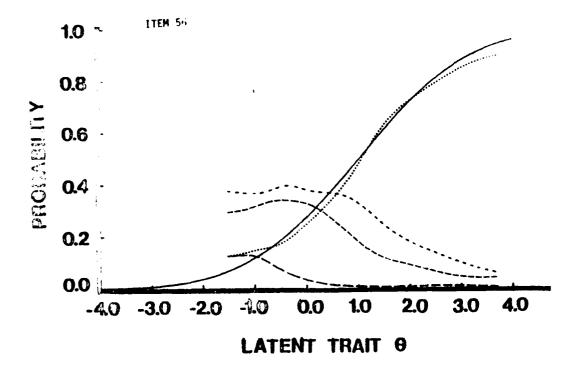
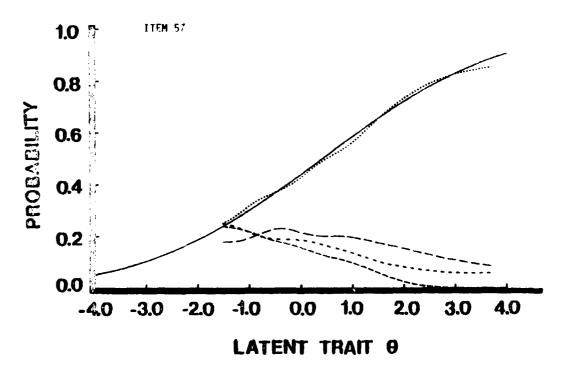
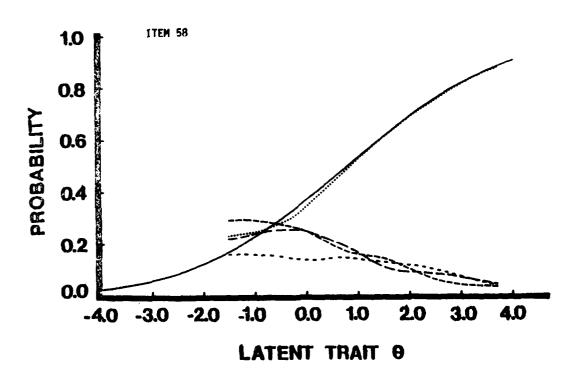


FIGURE 7-1 (Continued)





ifGURE 7-1 (Continued)



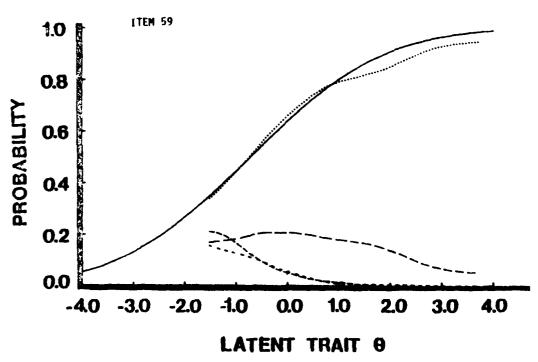
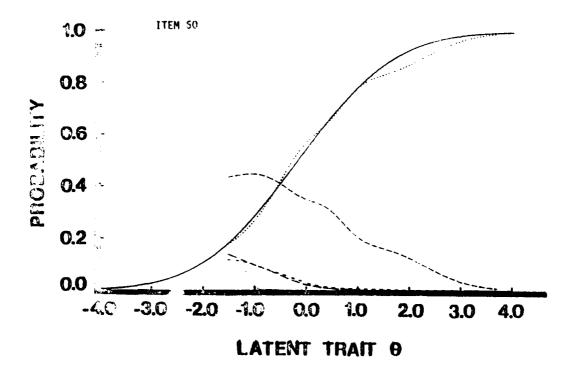


FIGURE 7-1 (Continued)



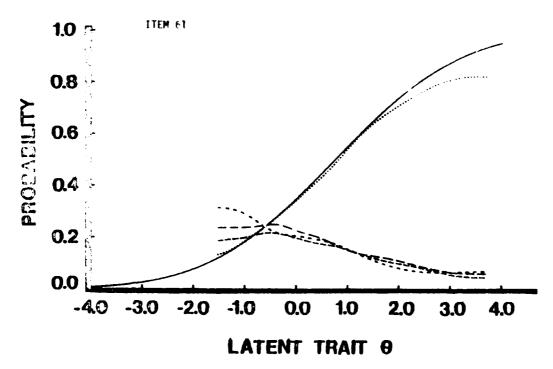
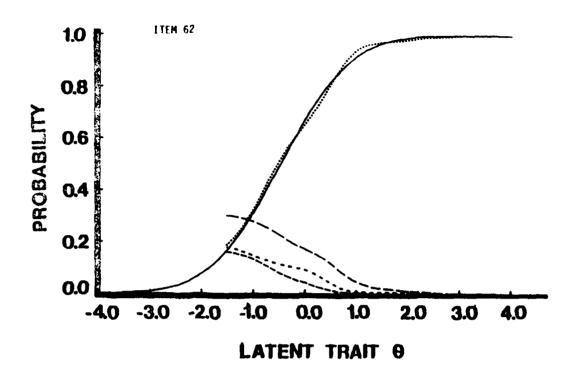


FIGURE 7-1 (Continued)



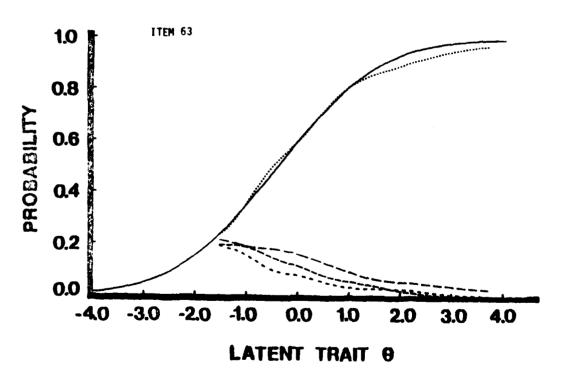
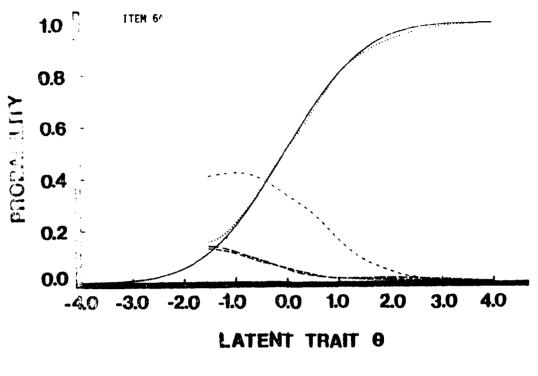


FIGURE 7-1 (Continued)



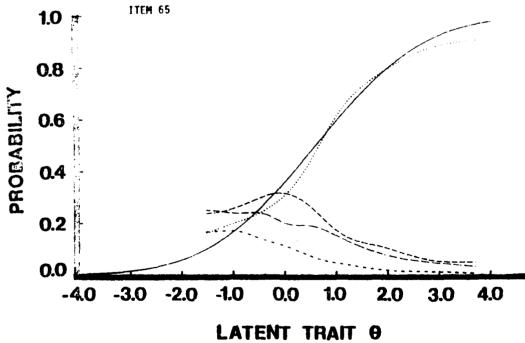


FIGURE 7-1 (Continued)

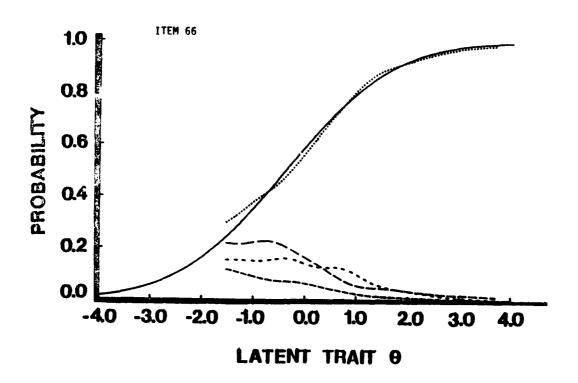


FIGURE 7-1 (Continued)

TABLE 7-2

Distractors Whose Estimated Plausibility Functions Proved to Be Informative, And Those Whose Estimated Plausibility Functions Are Unusually Flat.

Item	Informative	Flat
24		D
25	1	
26	C	į
27	÷ v	į
28	8	
29	1	1
30	В	
31	C	
32		
33		
34	D	
35	c	
36	D	
j 37	c,5	
38	8	
39	ן פ	B,C
40	C	
41	C !	8
42	i c	С
43	1	
44	. D	B,C,D
45	c '	

Item	Informative	Flat
46	C	
47	ם	
48	c	
49		8,0
50	8,0	
51	В	
52	В	
53	D	
54	c	3
5 5	В	
5 6	B,C	
57		8,9
58		B
59		D
60) c	
61	В	
62	D	
63		
64	В	
65	С	
6 6	Ì	

Note that the distractors listed in Table 7-2 are only those which proved to be informative from the results of the present study, in which the estimated operating characteristics are truncated on the lower levels of ability. There is no way of knowing about the information provided by distractors on the levels of ability lower than -1.6 , and it is suspected that there are many more informative distractors than those which the present results have disclosed. We shall be able to discover them by analyzing data collected upon a group of younger subjects in future research. Fourthly, we notice that there are some distractors which show unusually flat plausibility functions. They are listed in Table 7-2 under the label, "flat". Somehow those distractors attract high levels of subjects almost equally as they do lower levels of subjects. It will be worthwhile to use this information and go back to the items having such distractors to find out if the alternative answers selected for those items are suitable, or if the question itself is well addressed.

In any case, the above information provides us with valuable resources of item analysis. Effort can be focused upon the improvement of each item using this information, until we find a more informative set of alternatives.

We can see in Figure 7-1 that for some items the implicit orders of the distractors have been disclosed by the present research. For example, in item 46, the alternative C appears to be the second best answer, although the order between the alternatives B and D is not obvious. It may be appropriate to give the graded scores, 0,

I and 2, to the combination of B and D, to the alternative C and to the alternative A, respectively, for this item. Thus the three functions, which represent the cumulative operating characteristics assigned to \mathbf{x}_{45} (=0,1,2) or greater, were obtained from the result of Figure 7-1 and those graded scores, and are shown in Figure A-2 in Appendix. Similar functions were also obtained for sixteen other items and are shown in the same figure. In those seventeen graphs we can see that for items which were presented later in the subtest the operating characteristics for $\mathbf{x}_{\mathbf{g}} \geqslant 0$ decrease as θ decreases, disclosing a strictly decreasing operating characteristic for the "no answer" category.

Because of the confidentiality of the test, here we will not discuss the contents of the alternatives which proved to be informative, or which provide us with unusual configurations of the estimated operating characteristics, and so forth. It might be added, however, that in many cases we can find possible reasons for those characteristics of the estimated plausibility functions, although in some other cases we are rather puzzled.

VIII. Model Validation

We have seen in the results of previous sections that there is enough evidence to support the set of assumptions we adopted in the present research. First of all, the normal ogive model assumed for the Old Test items is well supported by the goodness of fit of the item characteristic functions estimated by assuming the normal ogive

model to those estimated by our combination of nonparametric method and approach. This result supports not only the assumed normal ogive model but also the multivariate normality assumed for the forty-three response tendencies.

It may be more appropriate to repeat the whole procedure after excluding such items as items 44, 39 and 49 from the Old Test, which do not show very good fits of the normal ogive functions. Considering the fact that there are only a few items of poor fits, however, we cannot expect the repetition of the procedure with the new reduced Old Test to provide us with a substantially different set of results. The decision was made, therefore, against it.

Secondly, the use of the Normal Approach Method is well supported by the estimated conditional moments of τ , given $\hat{\tau}_s$, which are shown in Appendix as Tables A-2 and A-3 and summarized in Table 7-1 in the preceding section.

In order to proceed further in model validation, the following procedure was added. For each pair of items, using their estimated normal deviates, $\hat{\gamma}_g$, which are presented in Table 5-4, and the estimated tetrachoric correlation coefficient between their response tendencies, the two-by-two contingency table is produced from the bivariate normal distribution. The chi-square statistic of the four frequencies in the actual contingency table was computed by using the frequencies in the contingency table thus produced as the "theoretical" values. Since the empirically obtained normal deviates and tetrachoric correlation coefficient are used in obtaining

the "theoretical" frequencies, the resultant statistic should have a negligibly small value, in order for the bivariate normal assumption to be validated.

As it turned out, most of the chi-square values are very small. Table 8-1 presents two such examples, i.e., those chi-square statistics for items 62 and 30, against each of the other respective forty-two items. In the same table, also presented are two more examples whose chi-square values are largest, i.e., those for items 24 and 44. In fact, item 44 has unusually large chisquare statistics in its row, as is obvious in this table. It is interesting to note that this item is the one which provides us with the poorest fit of the normal ogive curve to the nonparametrically estimated item characteristic function, as we have seen in Figure 7-1. In contrast to this, item 24 provides us with a surprisingly good fit, as is also seen in Figure 7-1. It is worth noting that these two items are the items whose estimated difficulty parameters are by far the largest in absolute value (cf. Table 5-4). Similar results for the other items are given in Appendix as Table A-4. In this table, all the chi-square statistics greater than, or equal to, 0.1 are circled. We can see that many items have small chi-square values against other items, except for those against items 44 and 24.

In order to investigate the relationship between the chi-square value and the goodness of fit of the normal ogive curve to the nonparametrically estimated item characteristic function, all the forty-three Old Test items are categorized into four classes, i.e.,

TABLE 8-1

Four Examples of the Sets of Chi-Square Statistics, Showing Good Fits (Items 62 And 30) And Bad Fits (Items 24 And 44) to the Bivariate Normality.

Item 62									
0.00918 0.00280 0.14038	0.00206 0.00298 0.00129	0.00260 0.00198 0.00196	0.00256 0.00764 0.00369	0.00174 0.00189 0.00181	0.00152 0.00609 0.00331	0.00124 0.00321 0.00593	0.00168 0.00181 0.00269	0.00110 0.00414 0.00219	0.00336 0.00152 0.00555
0.00314 0.00127	0.00159	0.00289	0.00665	0.00524	0.00218	0.00182	0.00358	**	0.00147
Item 30									
0.01794		0.00174	0.00200	0.00176	0.00142	0.00257	0.00107	0.00124	0.00600
0.07956 0.00305 0.00144	0.00126 0.00177 0.00298	0.00221 0.00363 0.00281	0.00188 0.00485	0.00162	0.00336 0.00254	0.00399 0.00174	0.00215 0.00350	0.0022/ 0.00124	0.00363 0.00193
Item 24									
****	0.02309	0.18162	0.70985	0.01323	0.01246	0.01794	0.15688	0.04920	0.16785
$0.01971 \\ 0.88370$	$0.13859 \\ 0.02561$	$0.01066 \\ 0.05016$	0.02627 0.03250	0.03445	$0.09895 \\ 0.02991$	0.02763 0.73564	0.02447 0.02281	0.01853 0.03418	0.03045 0.20828
0.03535	0.03341	0.01863	0.04813	0.13741	0.01430	0.01466	0.11926	0.00918	0.02732
Item 44									
0.88370	0.04498	0.22610	0.13053	0.13433	0.29440	0.07956	0.02398	0.71174	0.03705
0.05161	0.03860	0.20463	0.01998	0.02249	0.30588	0.01853	0.06475	0.02390	0.06416
0.0215		0.010/1	0.10999	0.02130	0.23/43	0.04360	0.02342	0.03017	0.09646
0.09809		0.02086			2	•			25.0

good, fairly good, fairly poor and poor, with respect to the goodness of fit inspected by the eye in Figure 7-1. Table 8-2 presents the item numbers thus categorized with respect to the goodness of fit and the frequencies of chi-square values greater than, or equal to, 0.1. We can see in this table that there is a negative correlation between the goodness of fit and the frequency of chi-square values which are greater than, or equal to, 0.1, the result which is logically expected. On the other hand, it is worth noting that there are a substantial number of items which have high frequencies of large chi-square statistics, and yet showing good fits of the normal ogive functions. This appears to indicate the robustness of the whole procedure used in the present research.

we notice from Table A-4 that most circles will disappear if we exclude those items which have thirteen or more circles in their rows. In fact, there are some which will not have any circles in their rows at all if we solely exclude items 44 and 24. For convenience, such items are categorized as Group A. If we further exclude those items having 19 to 2! circles in their rows, i.e., items 39, 50, 57, 33 and 37, then there will be more items which do not have any circles in their rows at all. This second group is called Group B. Similarly, Group C consists of the items which will not have any circles in their rows if we further exclude the items having 13 to 16 circles in their rows, i.e., items 53, 35, 42, 49 and 58. The rest of the items are categorized as Group D. Table 8-3 presents the item numbers of the thirty-one items classified

TABLE 8-2

Item Numbers Categorized with Respect to the Frequencies of the Chi-Square Statistics Which Are Greater Than or Equal to 0.01, And Also to the Goodness of Fit of the Normal Ogive Curves to the Estimated Operating Characteristics of the Correct Answer Obtained By the Simple Sum Procedure of the Conditional P.D.F. Approach Combined With the Normal Approach Method.

Frequency	Good	Fairly Good	Fairly Poor	Poor
1	62			<u> </u>
2	29, 30, 31, 45, 64	48		
3	25, 32, 46	60		
4	28, 36, 43	40		
5	55, 66	51, 52, 54, 61		
6	26, 38	41, 56, 63	Ì	
7		27, 65		İ
8	:	59	ľ	
9	34, 47		}	
13	58	42	49	
15	35			
16		53		
19	37			
20	33			
21	50, 57		39	
41	24			
42				44
Total Number	25	15	2	1

TABLE 8-3

Item Numbers of the Thirty-One Items Categorized with Respect to the Groups The, Belong to, and Also to the Goodness of Fit of the Normal Ogive Curves to the Estimated Operating Characteristic of the Correct Answer Obtained By the Simple Sum Procedure of the Conditional P.D.F. Approach Combined with the Normal Approach Method.

Group	Good	Fairly Good	
A	29, 30, 31, 45, 62, 64	48	
В	25, 36, 46, 55, 66	60	
C	26, 28, 32, 38, 43	40, 41, 51, 52, 54, 59, 61, 63, 65	
D	34, 47	27, 56	
Total Number	18	13	

with respect to the above categorization and the goodness of fit.

There is a substantial difference between the goodness of fit of

Group C and those of Groups A and B, as is expected.

We can say that the results of this additional process further support our whole procedure used in the present research.

IX. Discussion and Conclusions

A set of data based upon the Level 11 Vocabulary Subtest of the Iowa Tests of Basic Skills was analyzed, using the Simple Sum Procedure of the Conditional P.D.F. Approach combined with the Normal Approach Method, and the plausibility functions of the distractors of these items were estimated. In so doing, the same set of test items was used twice, i.e., once as the dichotomized Old Test items and then as the polychotomous test items whose characteristics are to be discovered. The results proved that most of the test items are not likely to follow the Equivalent Distractor Model, to which the three-parameter logistic or normal ogive model belongs. In fact, we have discovered many distractors which are informative, and the results suggest that most of these items follow the Informative Distractor Model. Model validation was performed from several different angles, and positive results were obtained.

Methodologies involved in the present study appear to be promising, and they will find their usefulness in many other future studies. It is the author's belief that more test data should be analyzed with the kind of rigorousness involved in the present study.

Since the results indicate that these test items belong to the Informative Distractor Model, the next logical step will be to find out how we can make the best use of the information obtainable from the distractors as well as from the correct answers, in order to increase the efficiency of ability estimation.

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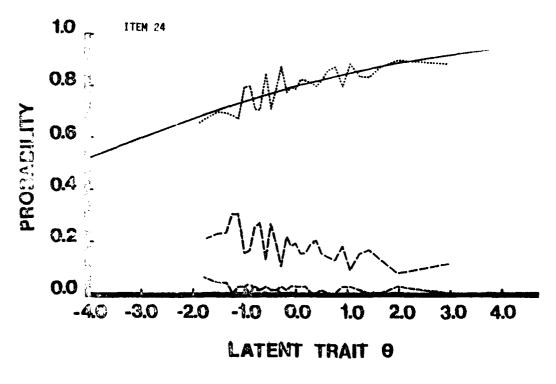
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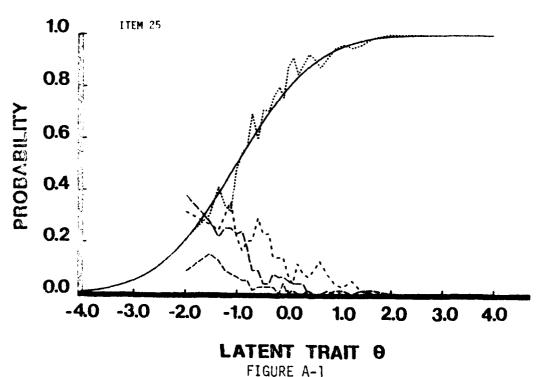
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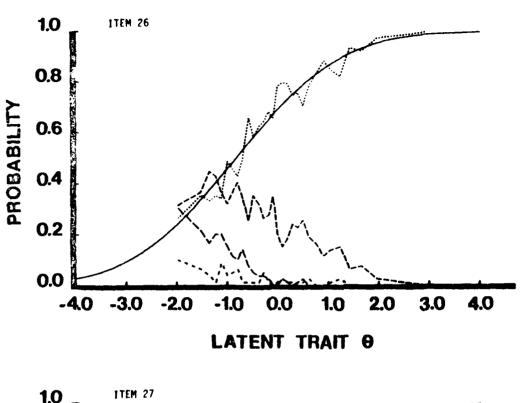
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APPENDIX





Frequency Ratios of the Maximum Likelihood Estimate $\,\hat{\theta}\,$ with Respect to the Choice of Each Alternative Answer, Together with the Item Characteristic Function (Solid Line) in the Normal Ogive Model with the Estimated Parameters. All the 2,361 Subjects Are Categorized into Thirty Unequal Subintervals of $\,\hat{\theta}\,$, Each of Which Contains 78 or 79 Subjects. The Mean of $\,\hat{\theta}\,$ Is Used As the Representative Value of Each Subinterval. The Ratios for the Correct Answer Are Plotted by Dots.



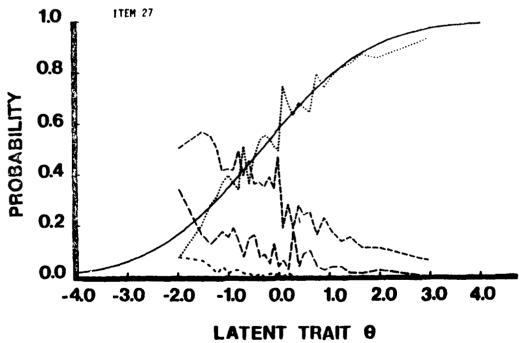
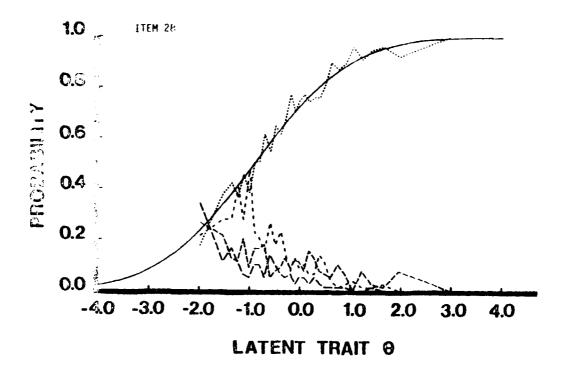


FIGURE A-1 (Continued)



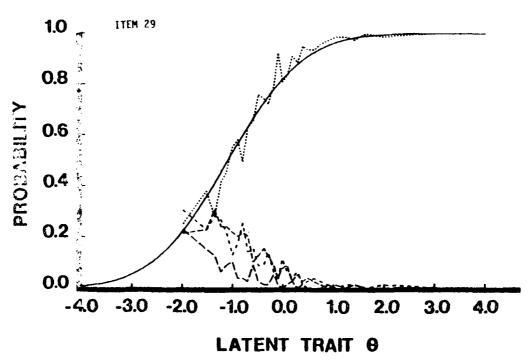
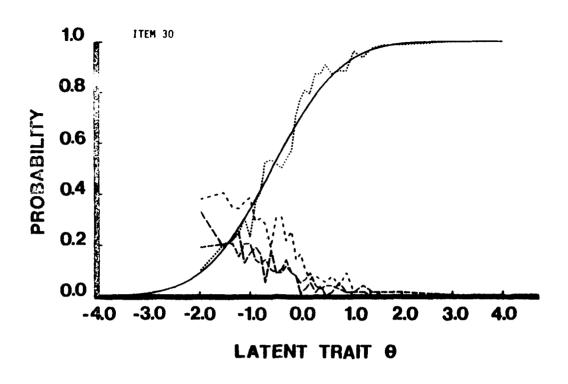


FIGURE A-1 (Continued)



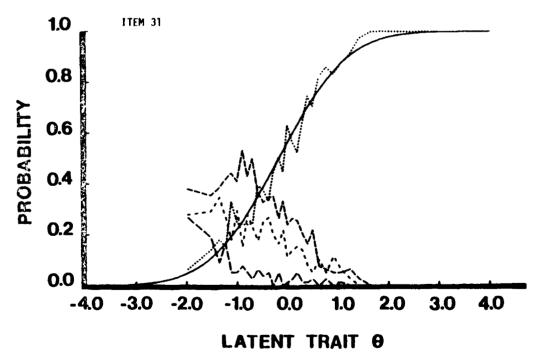
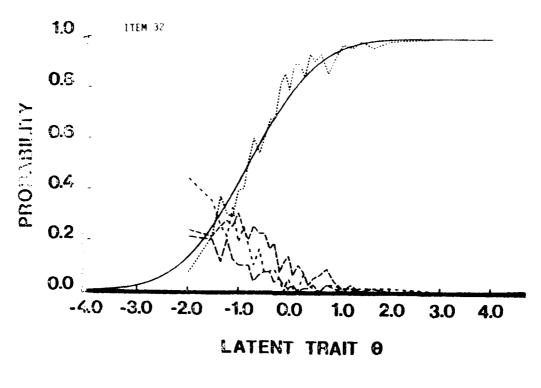


FIGURE A-1 (Continued)



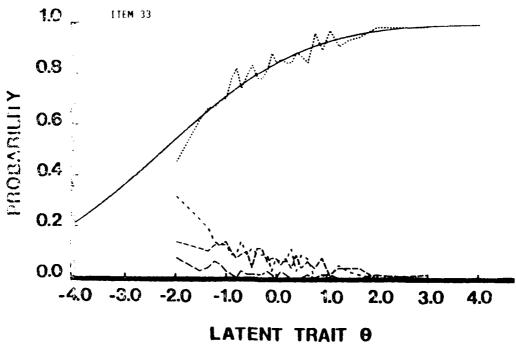
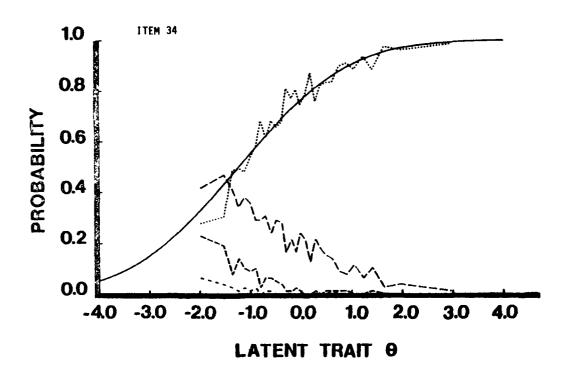


FIGURE A-1 (Continued)



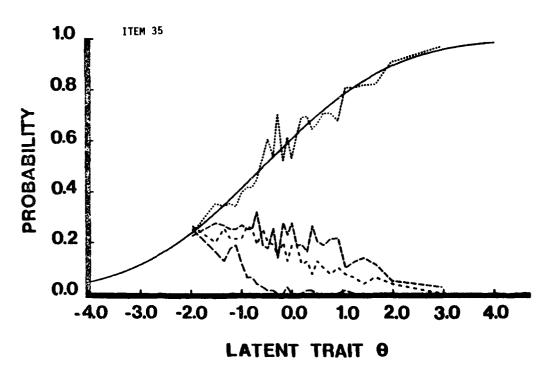
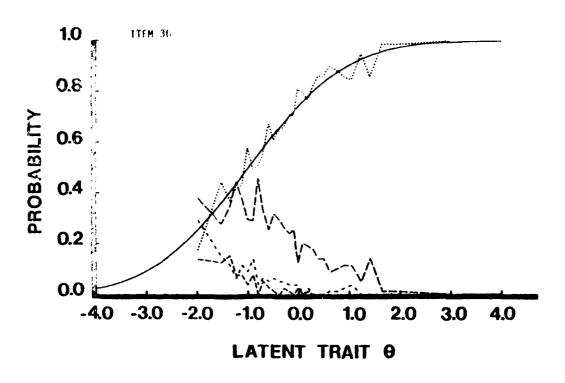


FIGURE A-1 (Continued)



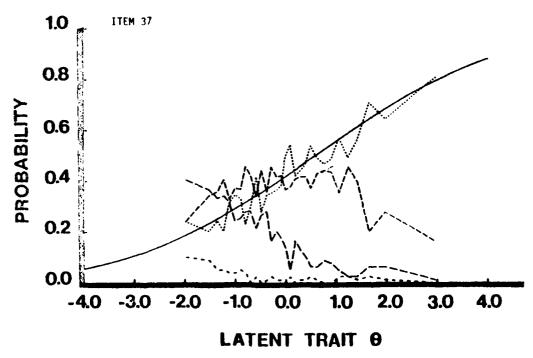
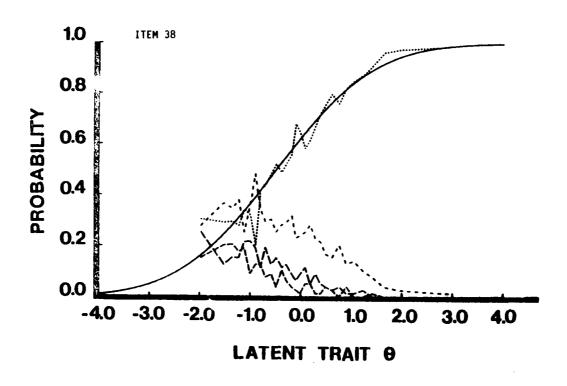


FIGURE A-1 (Continued)



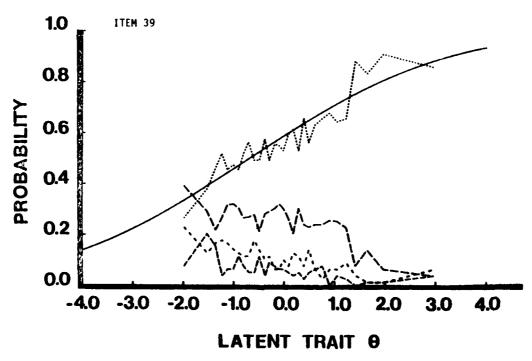
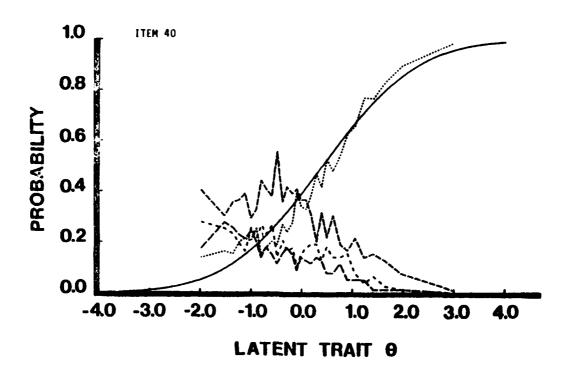


FIGURE A-1 (Continued)



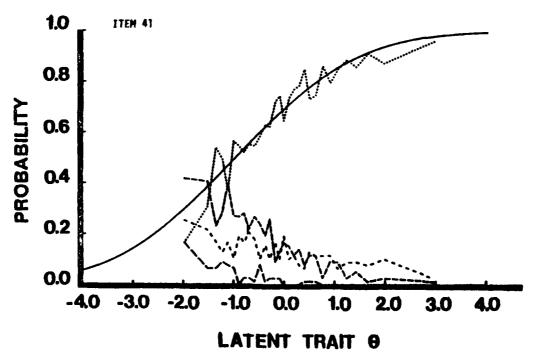
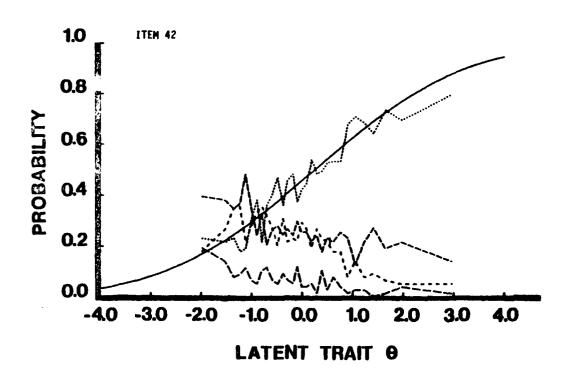


FIGURE A-1 (Continued)



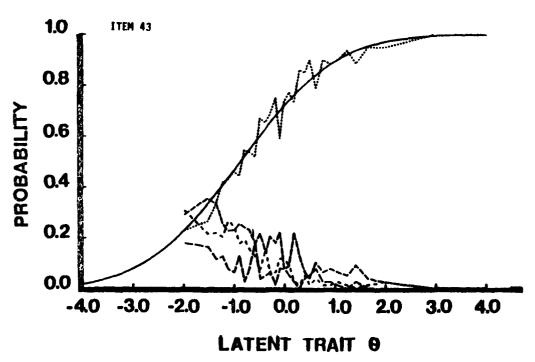
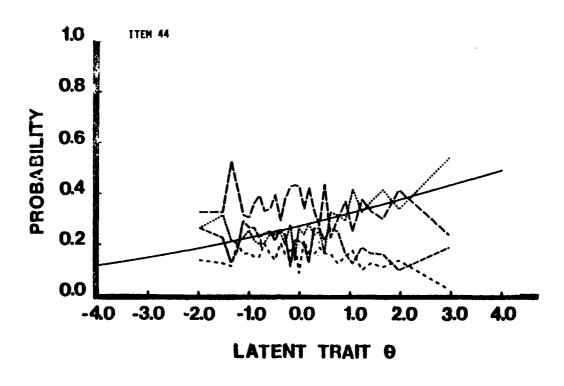


FIGURE A-1 (Continued)



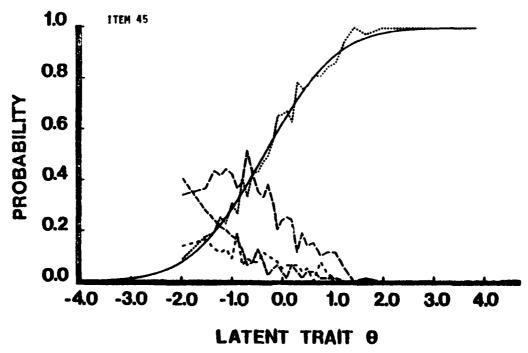
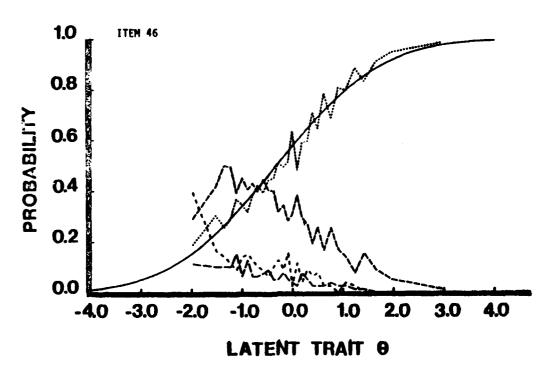


FIGURE A-1 (Continued)



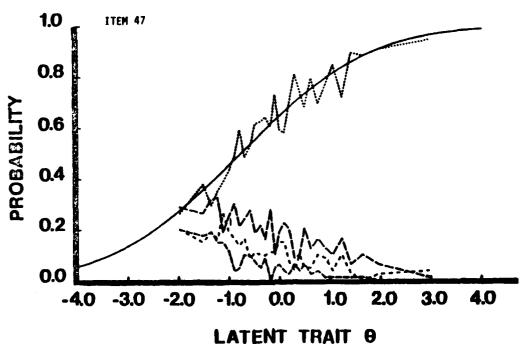
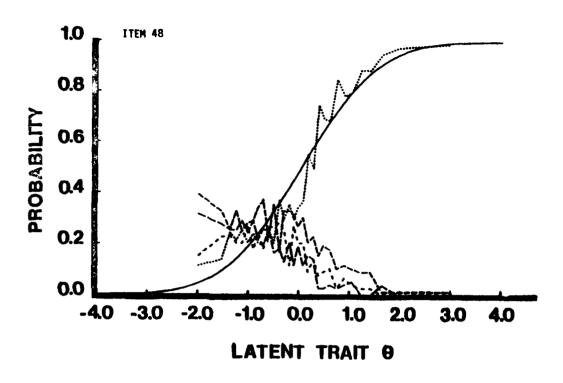


FIGURE A-1 (Continued)



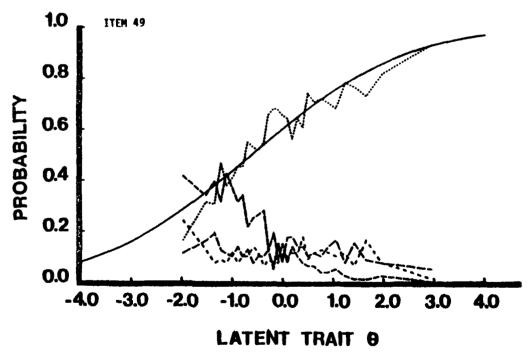
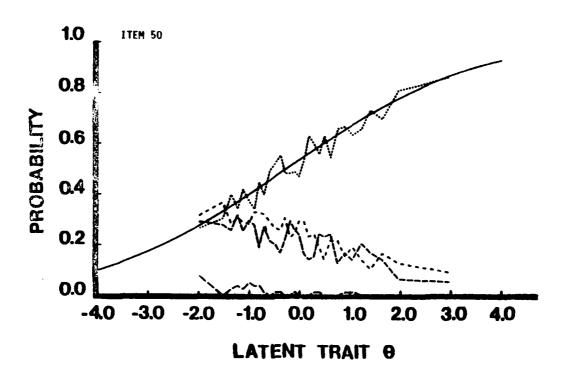


FIGURE A-1 (Continued)



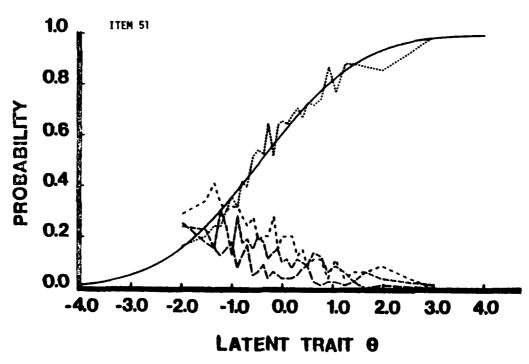
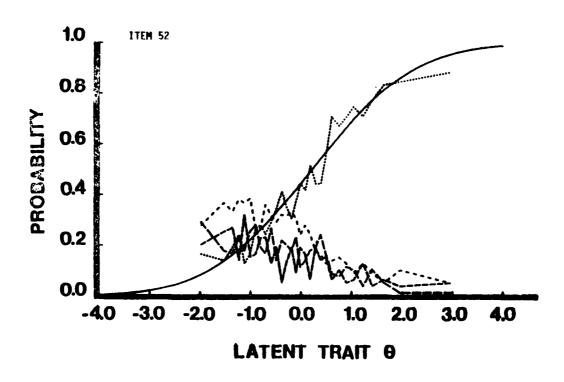


FIGURE A-1 (Continued)



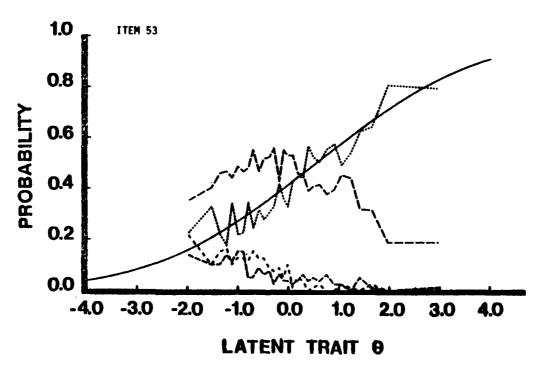
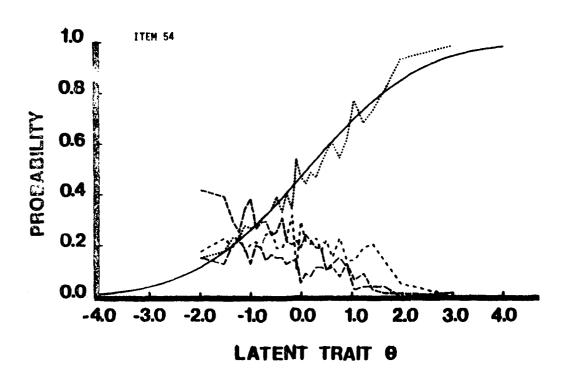


FIGURE A-1 (Continued)



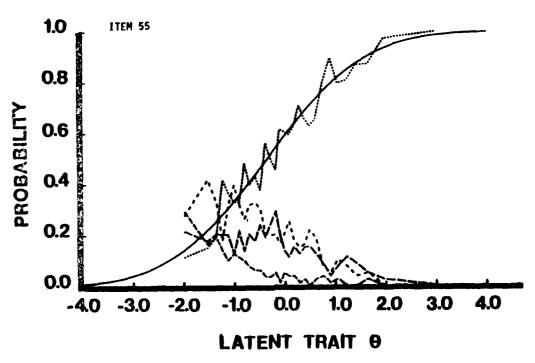
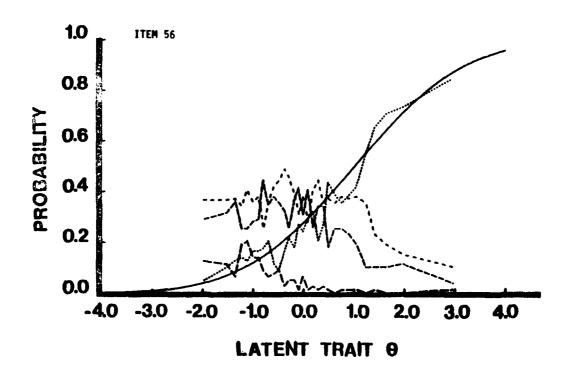


FIGURE A-1 (Continued)



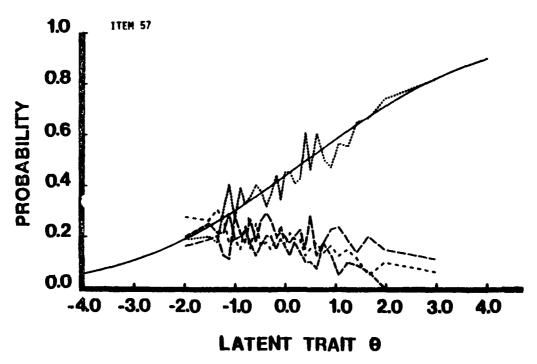
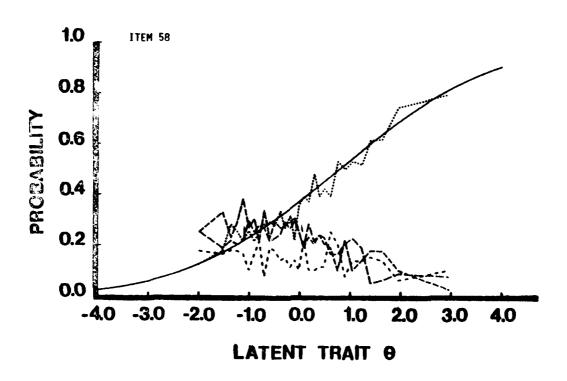


FIGURE A-1 (Continued)



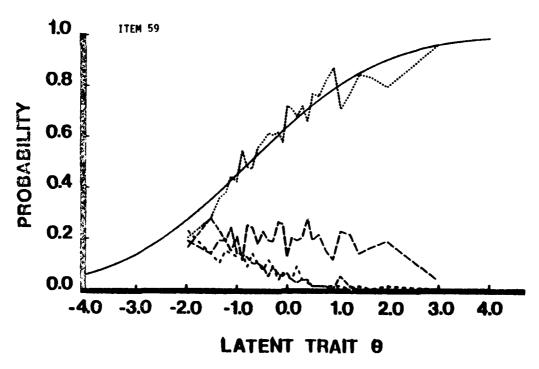
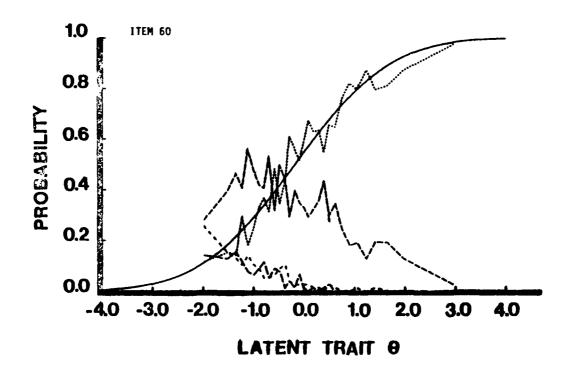


FIGURE A-1 (Continued)



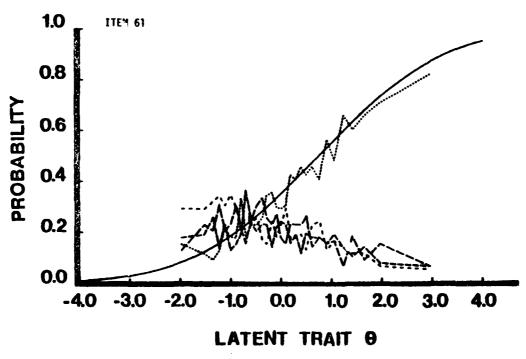
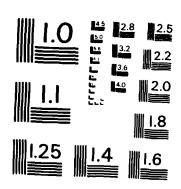
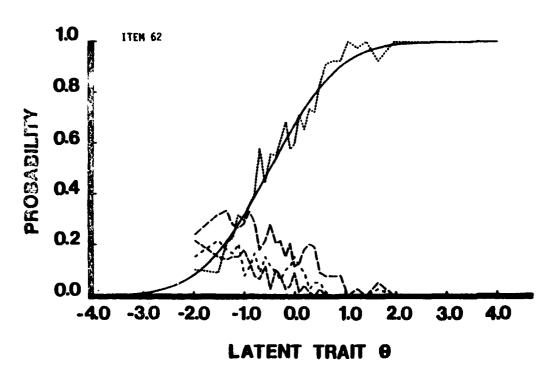


FIGURE A-1 (Continued)

PLAUSIBILITY FUNCTIONS OF IOMA VOCABULARY TEST ITEMS
ESTIMATED BY THE SIM. (U) TENNESSEE UNIV KNOXVILLE DEPT
OF PSYCHOLOGY F SAMEJIMA DEC 84 RR-84-1-ONR
N80814-01-C-0569 F/G 5/10 AD-8168 858 2/3 UNCLASSIFIED NL



MICROCOPY RESOLUTION TEST CHART NATIONAL BUREAU OF STANDARDS - 1963 - ...



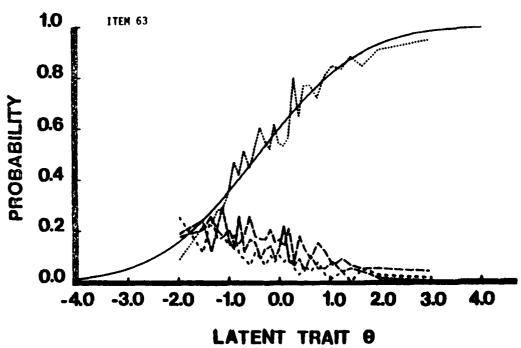
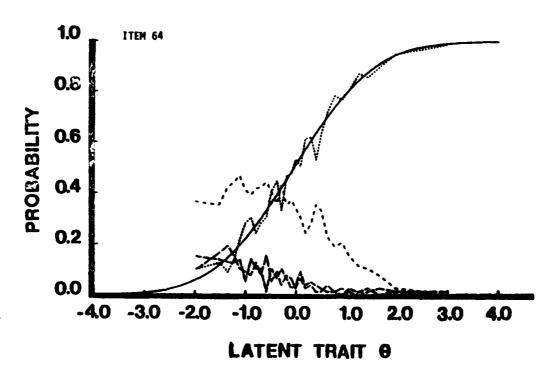


FIGURE A-1 (Continued)



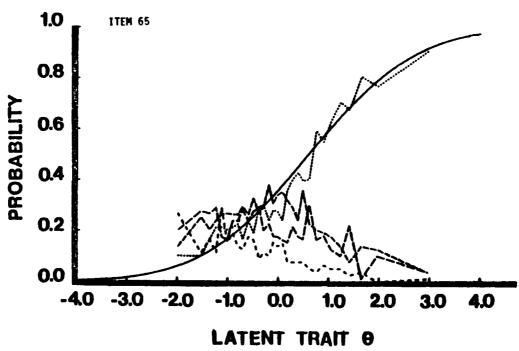


FIGURE A-1 (Continued)

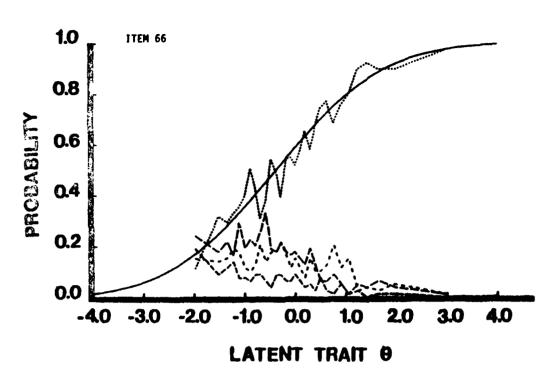
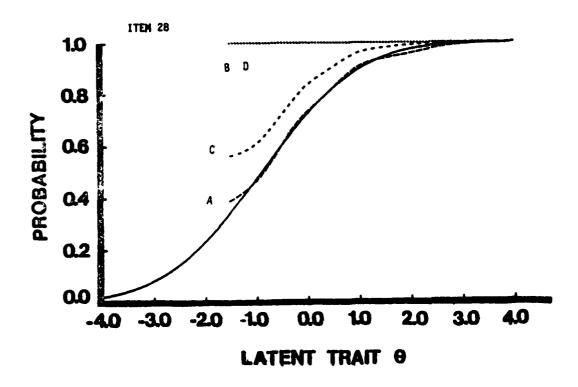


FIGURE A-1 (Continued)

...



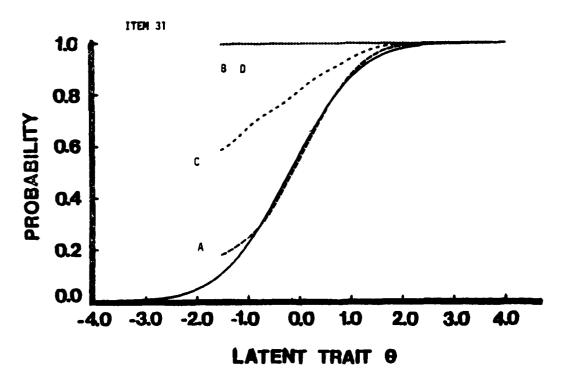
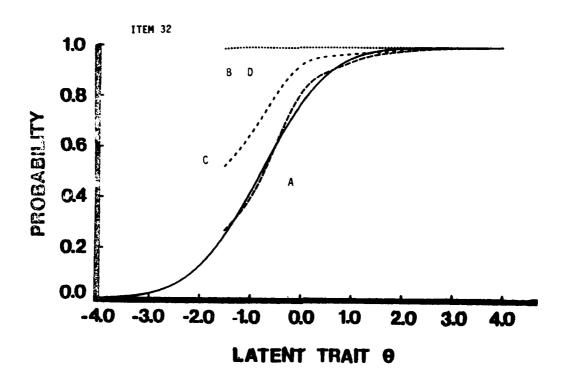


FIGURE A-2

Cumulative Operating Characteristics Drawn for Each of the Seventeen Selected Items, Together with the Estimated Item Characteristic Function Following the Normal Ogive Model (Solid Line).

<u>:</u>



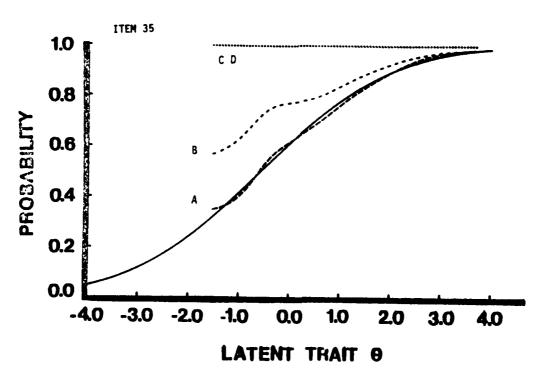
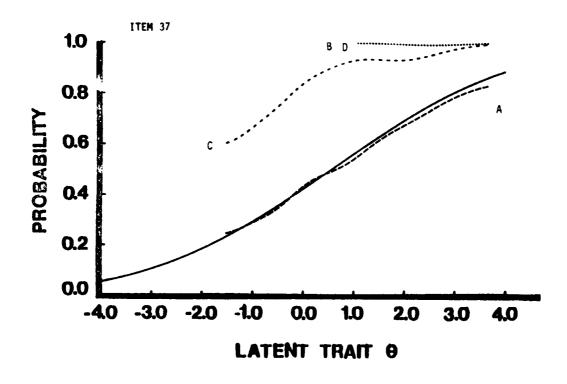


FIGURE A-2 (Continued)



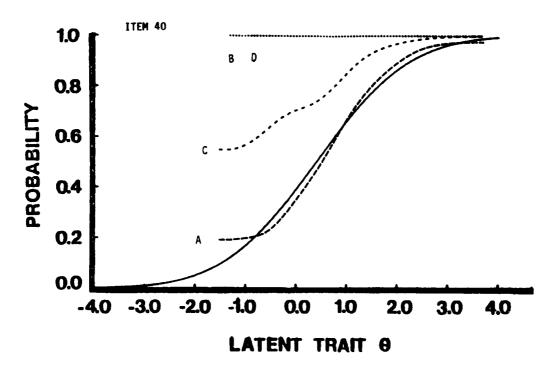
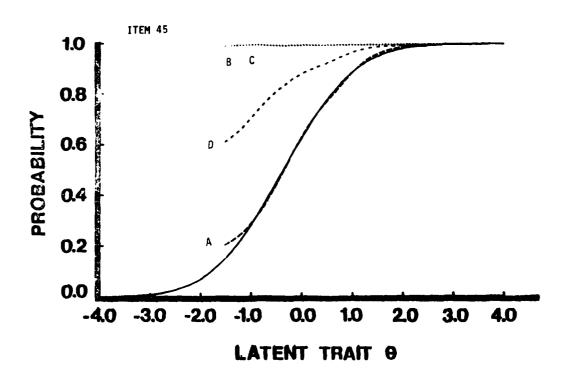


FIGURE A-2 (Continued)



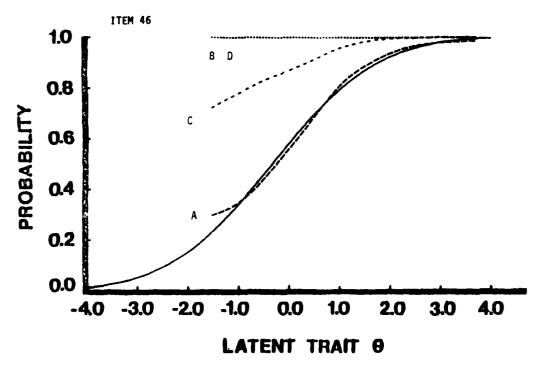
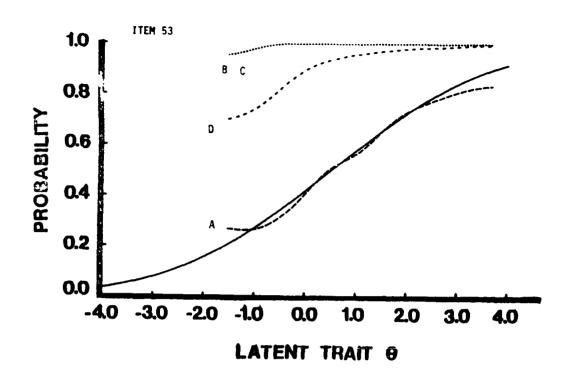


FIGURE A-2 (Continued)



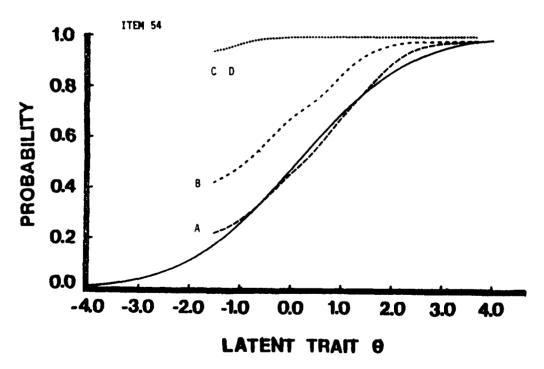
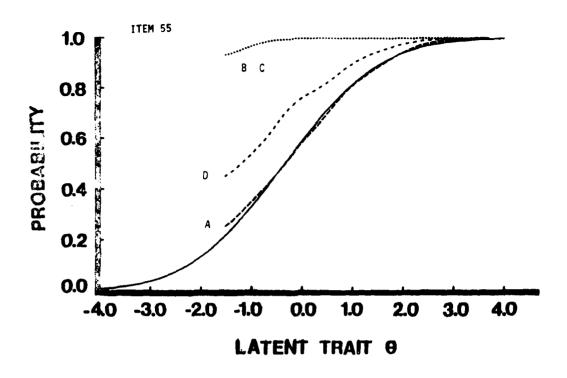


FIGURE A-2 (Continued)



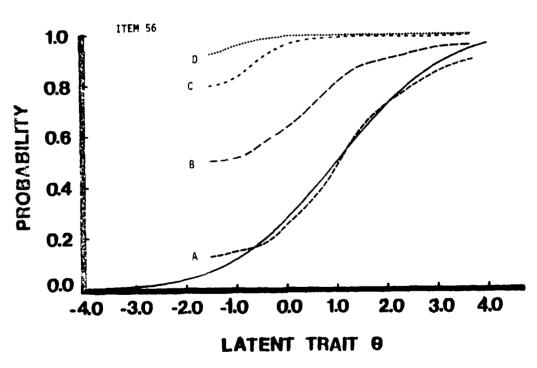
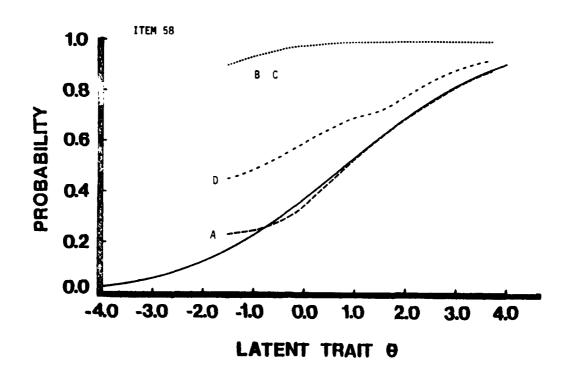


FIGURE A-2 (Continued)



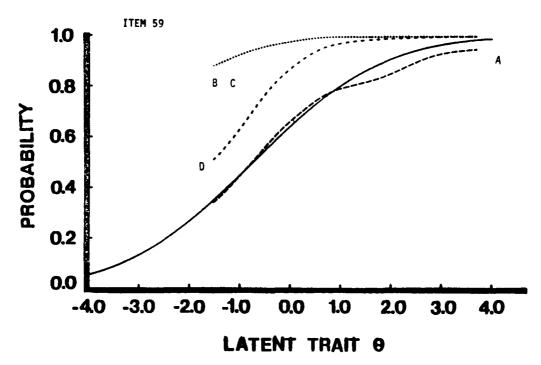
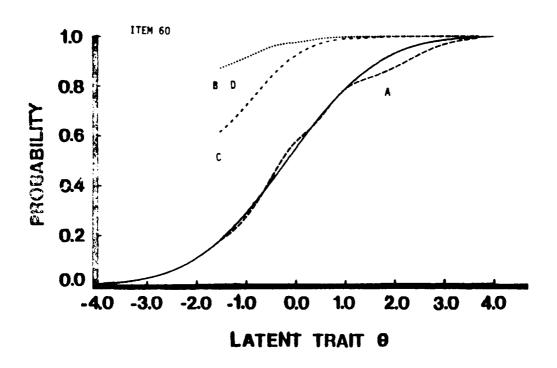


FIGURE A-2 (Continued)



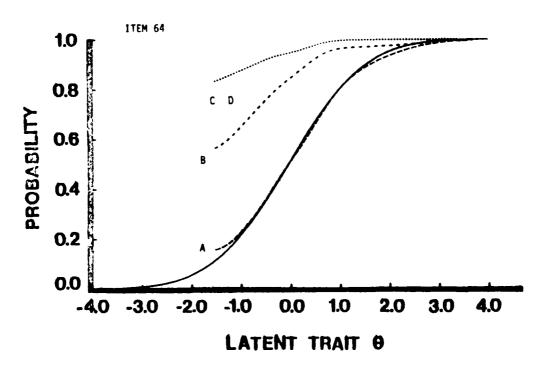


FIGURE A-2 (Continued)

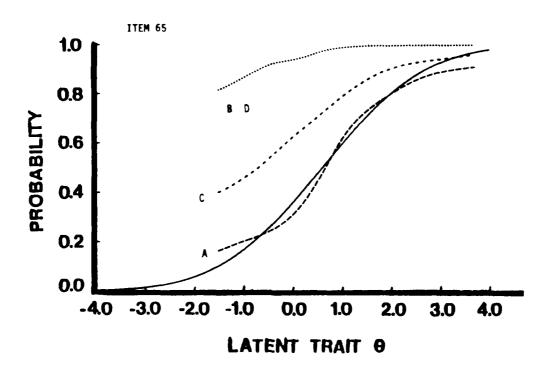


FIGURE A-2 (Continued)

TABLE F-1

Original, Revised And Rescaled Coefficients of the Polynomials of Degrees 3, 4, 5, 6 And 7, Obtained by the Method of Moments with Each of the Four Different intervals of a, for the Purpose of Approximating $[I(a)]^{1/2}$ of the Old Test, a=(-4.0,4.0).

(1) COEFFICIENTS OF THE POLYNOMIAL OF DEGREE 3

0.611448650-03	0.611448650-03	The second secon
34680034D-(Q+170162680±00 -0+105599220-01 -0+846800340-02 0+611448650-03	
	-0*105599220-01	
0.170162680+00	0 - 170162680+00	
ORIGINAL :	REVISED 4	

	0.177422730+00 -0.105599220-01 -0.130055310-01 0.611448650-03	0.611448650-03	
	-0,130055310-01	-0.105599220-01 -0.130055310-01 0.611448650-03	
COEFFICIENTS OF THE POLYNOMIAL OF DEGREE 4	-0.105599220-01	-0.105599220-01	27.787.787.78
(2) COEFFICIENTS OF THE POLYNOMIAL OF DEGREE 4	0.177422730+00	0.17422730+00	77.77.77.77.77
(2) COEFFICIENTS OF	ORIGINAL 1	REYISED E	
_			

URIGINAL :	0.330861360-03	0.17742273D+Q0 -0.1219486B-Q1 -0.13005531D-Q1	-0.130055310-01	0.108830150-02
REVISED #	0.177422730+00	-0.12194846D-01 -0.13005531D-01 -0.26822971D-04	-0.130055310-01	0,108830150-02

ORIGINAL .				
	0.180633860+00	-0.121948460-01: · · · · · · · · · · · · · · · · · · ·	· -0.172201370-01	0-108830150-02
REVISED :	07180613860+00	-0.121918460-01	-0.172201370-01	0.108830150-02
	0.112110010-02	-0.268229710-04	-01362192750-06	
(S) COEFFICIÊNTS OF T	OF THE POLYNOMIAL OF DEGREE	7		
ORIGINAL 1	0.180633860+00	-0.122968870-01	70.172201370-01	0.114559630-02
	0.11211001D-02	-0.347241210-04	-0.362192750-04	0,305229720-06
REVISED :	0.180633860+00	-0.12256887D-01	-0.172201370-01	0.114559430-02
	0.112110010-02	-0.347241210-04	-0.362192750-04	0.305229320-06

DEGREE 3 :	0.303036610+01	-0-188057980+00	-0.150803730+00	0-10890760-01
DEGREE 4 :	10+076596516-0	-0.188057980+00	-0.23161097D+00	10-10889076D-01
	0.589219480-02			
DEGREE 5 :	0.315965970+01	-0.217173770+00	-0.231610970+00	0-193811820-01
	0.589219480-02	-0.477680970-03		
DEGREE 6 :	0.321684550+01	-0.217173770+00	-0.306667430+00	0.193811820-01
	0.199652820-01	-0.477680970-03	-0.645016480-03	
DEGREE 7 :	0.321684550+01	-0.218990900+00	-0.306667430+00	0.204014910-01
	0.199652820-01	-0.618389800-03	-0.645016480-03	0.543572990-05

•

<u>.</u>
4.5
-4.5,
) = 0
(Continued)
A-1
TABLE

	0.452725670-03	0.452725670-03			0.452725670-03	0,452725670-03			0.104695570-02	9-10-695878-02			0-1946959TD-02	0.104445970-02				0.124302250-02	0.983433789-06	0.983433780-06		0.047446190-02	0.847646190-02		10-060470961-0	0.196024090-01	10-0377576	0.164130030-04
	-0.69058326D-02	-0.690583260-02			-0-118467850-01	-0-118487850-01			-0-118487850-01	10-05818481870-01	ما المارية	Communication of the communica	10-016 23 618 1,09 3	-0.[53983910-01	_			10-0163963810-01	-0.153983910-04	-0.190437630-04		F #0.12929911D+00	+0.221846880+00		00+0880+8177*0~	-0.288306770+00	-0.35655970D-03	-0.356559700-03
DEGREE 3	-0.910396750-02	-0.910396750-02	***	DEGREE 4	-0.910396750-02	-0.910396750-02		CREE 5	-0.116825190-01	-0.116825190-01		DEGREE 6	F	-0.264104010-04	-0.264104010-04	1 1	1	-0-123467690-01	-0.585854580-04	-0.585854580-04	<u> </u>	-0.170455180+00	-0.17045514D+00		-0.218733840+00	-0.218733840+00	-0.494486560-03	-0.109690580-02
THE POLYNOMIAL OF DE	0.157725480+00	0.157725480+00		THE POLYNOMIAL OF DE	0-167734960+00	0.284779150-03	U • 4 B4 ([9] > U = U2	THE POLYNOMIAL OF DEGREE	0.167734960+00	0.167734960+00		THE POLYNOMIAL OF DE	0-171157780+00	0.810646700-03	0.010646700-03	A	THE POLYNOHIAL OF DEGREE	9-171157790100	0.810646700-03	0.810646700-03	NTS AFTER SCALE CHANGE	0.295312100+01	0.314053100+01	0.533196990-02	0.533196990-02	0,320461730+01	10-021118600-01	0.15178800-01
(1) COEFFICIENTS OF	ORIGINAL :	REVISED 1	Control of the Contro	(2) COEFFICIENTS OF	ORIGINAL	REVISED :		(3) CUEFFICIENTS OF	UNIGINAL :	REVISED 1		(4) CUEFFICIENTS OF	ORIGINAL	REVISED 1			(5) COEFFICIENTS OF	ORIGINAL A	DEVICED	7	CURNECTED COEFFICIE	DEGREE 3 4	DEGREE 4 1		DEGREE 5 :	DEGREE 6 1		DECARE

TABLE A-1 (Continued) $\theta = (-5.0, 5.0)$.

	0.333411140-03	0.333611140-03			0,333611140-03		0.91199-03 0.91199-03		SEC. 01. 10. 01	4.91150-03				0.134917090-02	0.941793890-06		20-00610019-0	0.619043900-02	0.178401570-01	0-17840157D-01	0.262682590-01	
	-0.570805560-02	-0.57080556p-02		:	-0.107163590-01	-	-0.107163590-01		10-06886901	-0-117129400-04 -0-140438990-01	-0-11115940D-04	会の一般ながらい		-0.140438990-01	-0.1171		00+018020810+00	-0.208487870+00	-0.208487870+00		-0.227876450-03	
DEGREE 3	-0.180120950-02	-0,789720950-02		DEGREE 4	-0.180720950-02	DEGREE 5	-0,109324600-01 -0,210016800-04 -0,109324600-04	-0.21001680D-04	.109324600-0E		-0,210016800-04	DEGREE 7	-0.121330490-01%	-0-121330490-01	-0.590382420-04	CHANGE	-0.151890060+00	-0.15189060+00		0	1	
QE, THE PULYNOMIAL.UF D	0.147567130+00	0.147567130+00	Company of the compan	THE POLYNOMIAL OF	0.160087890+00 0.233720840-03 0.160087890+00	OF THE POLYNOMIAL OF O	0.160087890+00 0.233720840-03 0.160087890+00	0.23372084D-03	0-164049250+00	0-633025610-03	0,633025610-03	OF THE POLYMONIAL DE U	0.164049250+00	0.164049250+00	0.633025610-03	CIENTS AFTER SCALE CH	0.287093370+01	0,311452630+01	0.454706300-02	0.454706300-02	0.123155780-01	0.123155780-01
(1) COEFFICIENTS DE		REVISED 1		(2) COEFFICTENTS OF	ORIGINAL : REVISEO :	(3) COEFFICIENTS OF	ORIGINAL :	TAN CORRECTIONS OF	1 1			(S) COEFFICTENTS OF	URIGINAL I	REVISED 3	7767.3.	CORRECTED COEFFICE	DEGREE 3 :	DEGREE A 1	DEGREE 5 :	DEGREE 6 :		DEGREE / :

TABLE A-1 (Continued) $\theta = (-5.5, 5.5)$.

	0.246471460-03	0.246571560-03		0.256471560-03	0.246471460-03		0.770717010-03	D. 170111910-83		ső-ájátítájai	0.710717010-03			0.126258690-02	0.731928570-06	0.731926570-06			0.494007040-02	0.494007080-02	0-154476170-01		17-71-181-181-181-181-181-181-181-181-18	0.253042070-01	10101101010
	-0.4 166 97200-02	-0.476697200-02		-0,96584222D-02	-0.965842220-02		-0.965842220-02	#0.96584222D-02		Ast and 1294 63990-01	-0-129483990-01	-0. 790978580-05	Ç.,	0.129483990-01	-0, 7909 8580-05	-0.129483990-01	· · · · · · · · · · · · · · · · · · ·		-0.955452580-01	-0,193585460+00	-0.193585460+00	00.0000	-0.158537230-03	-0.259527030+00	to_000000000
DEGREE 3	-0.668415520-02	-0.668415520-02	DEGREE 4	-0.668415520-02	-0.668415520-02	GREE 5	-0.155973880-01	-0.155973880-04	GREE 6	-0.100823900-01 6 ch		-0.155573860-04	DEGREE 7	-0.117353400-01	-0.513646530-04	-0.513646530-01			-0.133971700+00	-0.133971700+00	-0.202083110+00	-0.312621200-03	-0-312621200-03	-0.235213490+00	70-7071647010-
THE POLYNOMIAL OF DE	0.138976060+00	0.138976060+00	THE POLYNOMIAL OF DE	0.153772700+00	0.18852970-03 0.153772700+00 0.188650970-03	 THE POLYNOMIAL OF DEGREE	0.153772700+00 0.188650970-03	0.15377270D+00 0.18865097D-03	THE POLYNOMIAL OF DEGREE	0.156511630+00	0.158511830+00	0.51492964D-03	THE POLYNOMIAL OF DE	0.158511830+00	0.514929640-03	0.515929650-03		NIS AFTER SCALE CHANGE	0.278\$52160+01	0.308209320+01	0.378116470-02	0.378116470-02	0.103208250-01	0.317708050+01	***************************************
II) COEFFIÇIÊNIS UF	DRIGINAL :	REVISED 1	(2) COEFFICTENTS OF	ORIGINAL :	REYISED :	(3) COEFFICIENTS OF	ORIGINAL:	REVISED .	(4) COEFFICIENTS OF	DRIGINAL 1	REVISED 1		(5) COEFFICIÉNTS OF	DRIGINAL		KEVIDED I		CORRECTED COEFFICIEN	DEGREE 3 :	DEGREE 4 1	DEGREE 5 :	. 4		DEGREE 7 :	

TABLE A-2

Estimated Conditional Mean And the Second, Third And Fourth Conditional Moments About the Mean, Coefficients \mathbf{B}_1 And \mathbf{B}_2 , And Pearson's Criterion κ for Each of the 2,356 \mathfrak{f}_s 's . Degree 3 Case.

CONDITIONAL MEAN. 3 MUMENTS ABOUT MEAN OF TAU. GIVEN MLE TAU. AND PEARSON COEFFICIENTS AND CRITERICN KAPPA

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CRITERION							******	*****		•	••••••	••••••	•		•••••			•	•••••		•	•••••	*****		•••••	******		•	••••••	*****		*****	•••••	•••••	****		
8 E V A 2							•••••••	••••••	••••••	• • • • • • • •	•••••••	••••••	• • • • • • • • •		••••••	******		••••••	•••••		••••••	•••••••	******		*******	*******		••••••	************			•••••••	*******	*******			
86 TA 1							•••••••	•••••••	*****	•••••••	********	•••••••	•••••		••••••	******		•••••••	******		******	*******	*******		********	••••••		•	*******		******	*******	10438.794	4965-468	1042.476		
HEAN	VALUE	VALUE	VALUE	VALUE	VALUE	VALUE	-6517.56190	-3929-42981	-355.28083	-30.60094	-18.21708	-3.46647	-1.23545	76191-0-	-0.45571	-0.29875	-0-17085	-0-16750	-0.13279	\$0601.0-	-0.07280	-0.06948	-0.06081	-0-0-0- -0-040-0-	-0.04639	-0.04176	-0.03233	-0.02945	-0.02732	-0.02628	-0.02344	-0.02213	-0.0200\$	-0.01928	-0-01708		
MOMENTS ABOUT	A NEGATIVE	A NEGATIVE	A NEGATIVE	A NEGATIVE	A NEGATIVE VALUE	A NEGATIVE	635.16270	434.32879	71.18831	11.09027	7.45307	2.04936	0.89622	0.62307	0.39196	0.27351	0.16848	0.16559	0.13510	91801.0	0.07975	0.07656	0.06.820	0.05694	0.05411	0.04953	0.04014	0.03726	0.03513	0.03409	0.03049	0.02993	0.02784	0.02707	0.02228		
MQ1	P.G.F. ASSUMES	R.D.F. ASSUMES	P.O.F. ASSUMES	.O.F. ASSUMES	.D.F. ASSUMES	P.C.F. ASSUMES	-46.48611	-36.06712	-10.75849	-3.07073	-2.34151	-0.95426	-0.52346	-0-39744	-0.27528	-0.20333	-0-13006	-0.12786	-0.10376	16080*0-	-0.05462	-0.05149	-0.04307	-0-03114	-0.02804	-0.02288	7710.0-	-0.00820	-0.00550	-0.00415	0.00059	0.00135	.0042	0.00528	0.01219	~	Ţ.
MEAN	GRADUATED P	GRADUATED &	GRADUATED P	GRADUATED P.O.F.	GRADUATED P.D.F.	GRADUATED P	5.07052	4.25988	1.54714	0.04388	-0.17077	-0.69142	-0.91478	-0.99165	-1.07339	-1.12541	-1.18111	-1.18281	-1.20140	91 17-11-	-1.23773	-1.23985	-1.24535	-1.25241	-1.25407	-1.25660	-1.26126		-1.26230	-1.26248			-1.26244		-1.25976		-
MLE) (TAU)	-1.9174	-1.8475	-1.8463	-1.8426	-1.8244	-1.8061			-1.71733			9:	11.03466	9		-1.61502		-	-1.58287		2	:	-1.54361	3	-		-1.50427	-	-		: :	1.	•	•	-1.45652		$\cdot \mid$
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TABLE A-2 (Continued)

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• • • •	*****	:	******			****		*****	• • • • • • • • • • • • • • • • • • • •	: :	*****	0.130	0.168	*1+°0-	-0.355	-0.313	-0.138	-0.131	-0-118	0110	-0.105	-0.104	-0.102	-0.095	-0.089	-0°086	-0.082	-0.080	-0.080	-0.07	-0.075	-0.075	jö	-0.070	-0.070	-0.010	8	590°0-	-0.064	-0.063	-0.062	-0.061	190.0-			-0.054	-0.050
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143.464 93.368 55.488	42.392	15.380	9.653	7.388	5.804	4.407	2.541	2.420	1.178	1.725	1.505	1.237	6/1-1 0-896	0.823	0-802	0,703	0.546	0.521	164-0	0.420	0.408	0.401	0.350	0.349	0.309	0.268	0.257	0.245	0.24	0.224	0.211	0.206	0.176	0.17¢	0-171	0.171	951-0	0.142	0.132	0.129	0.119	0.116	911.0	901-0	0.105	101.0	0.00
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0.01444	0.02318	0241	0.02650	0278	0.02910	0.03249	0.03336	0.03361	0.03469	0.03533	0.03602	0.03700	0.03859	0.03900	0.03924	0.03975	0.04093	0.04115	0.04198	0.04213	0.04226	0.04248	0.04294	3429	0.04348	3	0.04427	**	0.04456	0.04483	0.0450	0.04567	0.04578	0.0450	0.04592	0.04593	0.04642	0	2440.	• •	.0473	****	0476	.0411	22	6040	1000
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TABLE A-2 (Continued)

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8972	8927	1.47653	328	0.03780	00 75	਼	1.043	æ.	0.432	•	2282
5589	5588	1.47679	1.32821	0.03111	-0.00752	ċ	1.049	0.536	0.404	•	2283
2.290	2290	1.47979	m, ,	0.03740	-0.00769	0.0	1.130		0.220	+	2284
1677	1677	01864-1	•	0.03498	98800-0-	0-0-	.63	•	•••••	•	2285
7677	7677	715051	76446.1	0.03395	~ 5500°0-	0-0-	2.243	••••	****	Φ.	2286
6673	223	001161	9	0.03295	99500.0-	0.0	. 12		****	•	2287
9677	***	1.51383	•	0.03261	-0.01005	100.0-	2.916	***	*****	•	2288
66.	5677	9/9/5-1	9 4	0.03213	0.010.0-	'	3.201	•	: :	•	2289
2000	1001	1. 534 49	0416671	20160.0	***	2	3.367	•	*	•	2290
1677	3209	1.52618	1000001	10000	12110.0-		804.4			<b>.</b>	2291
0000	2249	1.53155	1.35795	10000	8410.0-		100.			•	2622
300	2300	1.53322	1.35874	0.02922	-0.01185		5.426			<b>,</b> 0	2293
2301	2301	1.53368	1,35895	0.02913	-0-01189	0-0-	5, 722			٠ ۵	33.56
2302	2302	1.55948	1.36988	0.02361	-0.01502		17.140	••••••		- 0	2296
5 403	2303	1.56601	1.37227	0.02199	-0.01598		24.015	•	:	•	2297
2304	2304	1.56782	1.37290	0.02152	-0.01627		26.532	:	******	•	2298
2002	2305	1.56960	1.37350	0.02106	-0.01655		29.325	•	*****	•	556
906	2000	£ + 19 £ • 1	1 27 6 1	*******	10810-0-		62.042		•••••	•	2300
308	2000	1.59366	1.38023	0.010.0	-0.501928		20.08		*	•	2301
309	2309	1.59621	1.38083	0.01299	-0-02168		214.754			> 0	2902
310	2310	1.59895	1.38138	0.01202	-0.02233		287.263			- 0	2305
2311	2311	1.60002	1.38158	0.01164	-0.02259		323.897	••••••	:	٠ •	2304
2162	2312	1.60164	1.38187	0.01104	-0.02299		392.280	•	•••••	•	2306
2313	2313	1.60327	1.38215	0.01044	-0.02340		480.874		3	•	2307
5314	2314	1.61534	1.38371	0.00560	-0.02677		69.38	•••••••	:	•	2308
315	2315	1.62482	1.38424	0.00131	-0.02988		****	•••••••	•••••	•	2309
2316	2316	1.63503	3	-0.00388	-0.03380		****	*******	••••••	•	2310
2317	2317	1-64174	8	-0.00766	-0.03676		***	•••••••	••••••	•	2311
2318	2318	1.64422	1.38309	+1600°0-	-0.03794		••••	•••••	٠	•	2312
2319	2339	987/9-1	1.37436	-0.03033	-0.05610		****	****	:	•	2313
321	2321	1.68121	1157571	10760-0-	*1850-0- -0-04352	16060-0-				•	2314
3	222	1.69532	1.35939	0.05635	-0.07037					<b>&gt;</b> (	2315
2323	2323	1-69645	1.35840	-0.05580	-0.08085					• •	2316
324	2324	1.69890	1.35615	-0.05904	-0.08421		*****	****	:	• •	9167
2325	2325	1.70592	1.34897	-0.06901	-0.09490		*****	****		• •	23.00
2326	2326	1.71155	1.34234	-0.07807	-0.10483	,	*****	:	•	• •	2320
1351	2327	1.71392	1.33932	-0.08211	-0.10941	•	********	•••••••	••••••	•	2321
2326	2328	1.71639	1.33598	-0-08654	-0.11450	•	*****	:	•••••	•	2322
6282	2329	1.72077	1.32963	16460-0-	-0.12430	•	* * * *	••••	••••••	•	2323
2330	2330	1.72296	1.32623	E660°0	-0.12962	•	*****	:	:	•	2324
7337	23.32	1.125.12	1.32300	0.1035	27451-0-	•	*****		• •	<b>~</b> (	2325
2333	2333	1.73001	1.31416	-0.11503	-0.14896					<b>~</b> 0	2326
2334	2334	1.74716	1.27626	0-1642	-0.21523	•	***			- 0	33.78
2335	2335	1.75076	1.26641	-0.17720	-0.23397	•	*****	****		•	2350
2336	2336	1.75726	1.24666	0.2035	-0.27362	•	********	*******	*****	•	2330
2337	2337	1.76089	1.23437	-0.22013	-0.29971	-0.33223	*******		:	•	2331
2330	2339	1.77441	· -		10.56445	•		•		•	2332
340	2340	1796	: -	1967-0	77764-0-	• •				•	2333
2341	2341	1.79228	1.07226	0.4627	-0.76034	,				> 0	2334
2342	2342	1.806.87	٣,	0.6981	-1.32562	•	*****	:	:	•	3136
2343	2343	1.83615	٣.	2.1104	-6.40406	ī	•••••••	*******	•	•	2337
2344	2344	1.83615	0.366	Š	-6.40406	ĩ	*******	*******	•••••	•	2338
2345	2345	1.86337	-2,24830	.0754	-139.41278	<b>6</b>	:	ë	•	•	2339
9467	2346	80598.1	2.170		199.78209	A -	******	••••••	•••••	•	2340
2347	2347	1.87168	.219	.6592	-1504-72095	-205	******	••••••	•••••	•	2341
2368	9366	.000	OST AND	4	4	U					
ř	ξ.	9		•	ES A REGALIVE	VALUE				01	
2349	2349	1.8829	GRADUATED #	P.O.F. ASSUMES	ES A MEGATIVE	VALUE				9	

TABLE A-2 (Continued)

35c	2350 2350	1.443.1	UNACUATED P.C.F. ASSUMES A NEGATIVE VALUE	01
351	2351 2351	1.4493	CRAGUATED R.C.F. ASSUMES A NEGATIVE VALUE	2
352	2382 2382	0.619.1	ÜRADUATED P.O.F. ASSUMES A NEGATIVE VALUE	<u> </u>
151	2353 2353	1.9275	GRADUATED 8.D.F. ASSUMES A REGATIVE VALUE	01
354	2354 2354	1246-1	GRADUATED P.C.F. ASSUMES A NEGATIVE VALUE	01
355	:355 2355	1.9537	GRADUATED P.D.F. ASSUMES A NEGATIVE VALUE	93
356	9380 5386	1.9537	GRADUATED P.O.F. ASSUMES A NEGATIVE VALUE	01

Pearson's Types

Normal Distribution

Undefined Due to Negative Even Moment(s) .. .. თ თ

Undefined Due to Negative P.D.F. 10:

TABLE A-3

<u>.</u>..

Estimated Conditional Mean And the Second, Third And Fourth Conditional Moments About the Mean, Coefficients  ${\bf g}_1$  And  ${\bf g}_2$ , And Pearson's Criterion  $\kappa$  for Each of the 2,356  $\hat{\bf t}_3$ 's . Degree 4 Case.

103								~ €	<b>.</b>	n •0	~ 0	•	0:	11	:2:	<u>.</u>	2 2	11	<b>£</b> 0	2	21	3.2	54	<b>5</b> 2	27	9,	2 6	2 %	32	£ ;	<b>*</b> #	r <b>%</b>	32
TYPE	01	10	01	01	10	01	•	~ ~	o 0	• •	• •	• 0•	•	• •	· <b>D</b> - (	<b>.</b>	• •	•	• •	• •	•	•	<b>6</b>	<b>D</b> 0	•	٥.	<b>.</b> 0	• •	•	<b>6</b> (	> 0	r <b>O</b>	• 🗪
CRITERION							***	*****	•••••		******		***	•	*****		******	******	*****	******	• • • • • • • • • • • • • • • • • • • •	****	•••••		******	*****	*****	*****	••••••	•	******	•••••	•
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8ETA1							• • • • • • • • • • • • • • • • • • • •	•	******	******	****	*******	******	********	• • • • • • • • • • • • • • • • • • • •		*******	******		*******	********	*******	*******	571.663	436.043	284.914	142,430	79.745	68.720	61.584	35.444	•	14.197
ME AN	VALUE	VALUE	VALUE	VALUE	VALUE	VALUE	19654-4-	-2.45838	-1-10078	-0.89065	-0.40675	-0.21800	-0.17544	-0.09234	-0.07389	-0.06017	-0.05090	-0.04168	-0.03127	-0.03005	-0.02678	-0.02220	-0.02102	10.010-0-	-0.01441	-0.01356	-0.01209	-0.01072	-0.01035	-0.01008	-0.00665	-0.00752	-0.00616
MOMENTS ABOUT NEAN	A NEGATIVE	A NEGATIVE	A NEGATIVE	A NEGATIVE	A NEGATIVE	A NEGATIVE	2.50828	1.56713	0.82089	60	0.22007	0.21064	0.17442	0.09940	0.08176	0.06897	0.05920	0.04995	0.03941	0.03816	0.03482	0.03014	0.02893	0.02269	0.02219	0.02134	5	0.01845	5	0.01780	ខ	3	2
7	P.C.F. ASSUMES	P.C.F. ASSUMES	.C.F. ASSUMES	P.D.F. ASSUMES	.O.F. ASSUMES	P.D.F. ASSUMES	-1.10365	2.3			-0.16997	533	-0-13696	-0.07536	-0.05882	-0-04605	-0.03576	-0.02548	-0.01293	-0.01138	-0.00713	-0.00093	0.00012	0.00966	0.01041	0.01169	0.01403	0.01622	0.01682	0.01726			.0238
MEAN	GRADUATED P	GRADUATED P	GRACUATED P.C.F.	GRADUATED P	GRADUATED P	GRADUATED P	-0.63056	-0.77773		2,0	-1.16101	-1.16613	-1-18674		-1.24710			•			-1.27556	-27		-1.27412			-	-1.26994	7.	15997-1-	7	-1.26395	-1.26029
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TABLE A-3 (continued)

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TABLE A-3 (Continued)

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TABLE A-3 (Continued)

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TABLE A-3 (Continued)

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0.19876	0.19911	9661.0	0.20158	0.20284	0.20402	0.20734	0.20809	0.20923	0.21160	0.21270	0.21278	0.21359	0.21570	0.21606	0.21634	0.22124	0.22159	0.22234	0.22494	0.22552	0.22567	0.22646	0.22715	0.22794	0.23071	0.23101	19767-0	0.23648	0.23790	0.23799	0.23966	0.23994	0.24145	0.24151	0.24164	0.24247	0-2420	0.24317	0.24350	0.24440	0.24676	0.24985	0.25021	0.25186	0.25406	0.25767	0.25786	0.25934	0.26016	0.26111	0.26459	0.26572	0.26621	0.26743
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TABLE A-3 (Continued)

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TABLE A-3 (Continued)

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TABLE A-3 (Continued)

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1.00903 1.00956 1.01021 1.01190 1.01337 1.01702 1.01941 1.02132	1.02652 1.03664 1.03664 1.03664 1.03674 1.03664 1.04035	1.04412 1.04622 1.04742 1.04742 1.04934 1.05097 1.05158 1.05169 1.05169	1.06461 1.06527 1.06527 1.07848 1.07898 1.07804 1.08024	1.08109 1.08185 1.08351 1.08449 1.08567 1.08567 1.09671 1.09771	1.10777 1.10777 1.10787 1.110899 1.11223 1.11622 1.11622 1.11632 1.12533
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0.05548 0.05548 0.05548 0.05546 0.05588 0.05588 0.05586 0.05666 0.05617	0.05988 0.05988 0.05080 0.050810 0.051111 0.05164 0.0550 0.0550 0.05541 0.05540 0.0574	0.01558 0.01558 0.01558 0.01558 0.01581 0.01959 0.08118 0.08117 0.08236 0.08381	0.09054 0.09154 0.09538 0.09538 0.09591 0.10062 0.11351 0.12065 0.12065 0.12467 0.12467 0.12467 0.12467 0.12467
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TABLE A-3 (Continued)

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2-170 2-177 2-177
0.000
0.03719 0.03716 0.03716
-0.00006 -0.00269 -0.00269
0.13091 0.13065 0.13065
1.97201 1.99631 1.99631
1.95366 1.95366 1.95366
2355 2355 2356

2356 2355 2356 YPE 1-7 : Pearson's Types

: Normal Distribution

: Undefined Due to Negative Even Moment(s)

O : Undefined Due to Negative P.D.F.

TABLE A-4

Chi-Square Statistics Obtained for Each Pair of the Forty-Three Items.

	+	; 1			!	
	0.00144 0.00212 0.00120 0.00261	0.00456 0.00346 0.00784 0.00487	0,00530 0,00307 0,00842 0,00310	0.00.0177 0.00.0145 0.00.0550	0.00180 0.00595 0.00595	0.00217 0.00313 0.00363 0.00193
81630.0 0.003410.0	0.00111 0.00383 0.00277 0.00206	0.00204 0.00268 0.00260	0.00229 0.00726 0.00271 0.00256	0.00142 0.00529 0.00354 0.00174	0.00101 0.00431 0.00464 0.00152	0.00124 0.00411 0.00227 0.00124
STATE OF THE PARTY	0.00168 0.00309 0.00206 0.00573	0.00198 0.00513 0.00370 0.00573	0.00208 0.00322 0.00352	0.00197 0.00554 0.00298 0.00892	0.00185 0.00266 0.00210 0.00593	0.00107 0.00452 0.00215 0.00350
	0.00124 0.00305 0.00979 0.00260	0.00174 0.00372 0.00406 0.00315	0.00200 0.00634 0.02839	0.001 % 0.02015 0.02015	0.00142 0.00408 0.00931 0.00275	0.00359 0.00399 0.00174
	0.00135 0.00451 0.00536	0.01329 0.01329 0.00919 0.00741	0.00537	0.00190 0.00772 0.00708 0.00317	6 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0.00142 0.00335 0.00336
	0.00160 0.00244 0.00212 0.00642	0.00337 0.00290 0.00200 0.00838	0.00336 0.00385 0.00216 0.00524	0.00481 0.00283 0.00812	0.00190 0.00184 0.00219 0.00838	0.00178 0.00205 0.00162 0.00401
1877:00 1877:0	0.00330 0.00693 0.00330 0.00782	0.00298 0.01069 0.00305 0.01093		0.00336 0.00937 0.00825 0.00877	0.00255 0.00785 0.00336 0.00740	0.00200 0.00588 0.00188
	0.00210 0.00282 0.00287 0.00486	0.00437 0.00437 0.00680 0.00680	0.00298 0.00197 0.00359 0.00791	0.00332 0.00322 0.00300 0.00300	0.00221 0.00134 0.00301 0.00301	0.00174 0.00228 0.00221 0.00383
	0.00519 0.00162 0.00238 0.00238	0.00210 0.00241 0.00263 0.00296	0.00230 0.00249 0.00199 0.00408	0.00160 0.00363 0.00192 0.00257	0.00135 0.00172 0.00172 0.00400	0.00124 0.00124 0.00126 0.00177
	0.00230 0.00230 0.00230 0.00230 0.00230	0.18162 0.00481 0.22610 0.00422 0.00433	0.000380 0.000380 0.000320	0.00323	0.2450 0.00183 0.007350 0.007350	0.00195 0.00195 0.00195 0.00195 0.00195
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TABLE A-4

0.00351 0.00307 0.01346 0.00536 0.08213 0.08213 6.00253 0.00338 0.00262 0.00228 0.00537 0.00537 0.00855 0.00240 0.00497 0.00291 0.00283 0.00140 0.00637 RE-1000 Participants 0.00336 0.00336 0.00207 0.00461 0.00296 0.00189 0.00182 0.00973 0.00486 0.00156 0.00663 0.00394 0.00198 0.00683 0.00993 0.00812 0.00170 0.00158 0.00247 0.00183 0.00188 0.00115 0.00110 0.0025 0.0044 0.00659 0.013259 0.00818 0.00980 0.01927 0.00305 0.00301 0.00301 0.00384 0.00385 0.00305 0.00177 0.00340 0.00156 0.00205 0.00154 0.00605 00229 00281 00279 00948 0.00197 0.00482 0.00215 0.00481 0000 0.00566 0.03170 0.00712 0.00222 0.01020 0.01022 200000 200000 200000 200000 0.00228 0.00553 0.00407 0.00348 0.00328 0.00848 0.00209 0.00242 0.00600 0.00101 0.00134 0.00503 0.00207 0.00124 0.00326 0.00800 0.00214 6001000 0.00125 0.00725 0.00725 0.001955 0.0150 0.0150 0.0150 0.0150 0.00703 1.01503 1.01503 0.00101 0.00570 0.00435 00185 00816 00488 00334 00134 00680 00565 00542 0000 0.00112 0.00125 0.00135 0.00417 0.00855 0.00826 0.22662 0.00559 0.00559 0.00108 0.00638 0.00638 0.00387 0.00197 0.00112 0.00112 0.00142 0.00207 0.00211 0.01613 0.00322 0.00524 0.00274 0.00772 0.00245 1000 E 6.05259 0.0010 0.0320 22210 0.00385 0.00559 0.00665 0.00208 0.00508 0.00316 0.00402 0.00229 0.00683 0.00399 0.00871 0.00641 0.00388 0.00468 0.01063 0.00487 0.00213 0.00503 0.01061 0.00640 0.01329 0.00880 0.00902 0.00728 0.30456 0.00399 0.01240 0.01965 0.000 000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0. 00524 00524 00426 00426 00198 00229 00223 00225 00225 0.00204 0.00158 0.00252 0.00437 0.00437 1500 CO 0.0026 0.00519 0.00298 0.00518 0.00 54 J 0.00168 0.00274 0.00128 0.00193 0.00111 0.00186 0.00113 0.00225 0.00225 00174 00762 00353 00373 00583 00 28 2 00 38 8 00 19 1 00 45 2 00000 0.00000 0.30588 0.00746 0.00705 0.1568 0.00284 0.00203 0.00146 0.0056 0.0056 0.00577 0.003859 0.003862 0.00387 0.00833 20.00 = I tem Item I tem Item Item Item

TABLE A-4 (Continued)

2 0.001302 7 0.00464 1 0.00464	0 0.00894 0.00425		0 0.00592 8 666666 6 0.00691 2 0.00343		3 0.00457 6 0.00175 6 0.00510 9 0.00267	2 0.01290 3 0.00262 0 0.00772 6 0.00348	6.00.53 6.00.53 6.00.751	0.00626
0.00928 0.00442 0.00317 0.00317	0.00108 0.00108 0.00108	0.00438 ********* 0.00483 0.00414	0.00140 0.00598 0.00406 0.00152		0.00113 0.00428 0.00216 0.00129	0.002\$2 0.00743 0.00390	0.00369 0.00589 0.00369	0.00211
0.00134 0.00651 0.00344 0.00405	0.00429 0.00388 0.00970	0.00281 0.00658 0.00733	0.00253 0.00319 0.00223 0.00792		0.00128 0.00355 0.00212 0.00288	0.00223 0.00481 0.00431 0.00579	0.00316 0.00686 0.00642	0.00112
0.00257 0.00978 0.00247	0.00492 0.00451 0.01125 0.00455	0.00411 0.00412 0.00378	0.00217 0.00402 0.00651 0.00273		0.00126 0.00245 0.00424 0.00424	0.00221 0.00352 0.00688 0.00386	0.00188 0.00352 0.00754 0.00474	0.00162
0.00408	0.00266 0.00980 0.00430 0.00941	824E0.00	0.00180 0.00856 0.00494 0.00490		0.00172 0.00769 0.00344 0.00290	0.00301 0.00902 0.00523 0.00618	0.00336 0.00349 0.00864	0.00219
0.00363 0.00242 0.00166 0.00417	0.00554 0.00462 0.00366 0.00761	0.00529 0.00461 1.00177 0.0177	0.00344 0.00240 0.00244 0.01702		0.00192 0.00207 0.00127 0.00571	0.00300 0.00250 0.00205 0.00541	0.00825 0.00465 0.00334 0.00618	0.00263
0.00578 0.00578 0.00443	0.00322 0.0158 0.00586 0.09368	9.0072 9.00128 14.00128	0.00307 0.00917 0.00654		0.00199 0.00547 0.00399 0.00594	0.00359 0.00815 0.00372		0.00216
0.00312 0.00553 0.00352 0.00224 0.00349	0.00613 0.00281 0.00461 0.00850	0.00563 0.00863 0.00898 0.00898	0.00346 0.00228 0.00262 0.00627		0.00263 0.00191 0.00188 0.00290 0.00313	0.00437 0.00497 0.00450 0.00450	0.00309 0.00379 0.00372 0.00792	0.00200
0.00308 0.00328 0.00245 0.00245 0.00236	0.00309 0.00305 0.00355 0.00412	0.00183 0.00183 0.00163	0.00212 0.00389 0.00175 0.00279		0.00162 0.00298 ******** 0.00164 0.00288	0.00287 0.00468 0.00188 0.00259	0.00493 0.00493 0.00439 0.00439	0.00212
0.00754 0.00754 0.00754	0.002445	0.00338	0.00238		0.00201 0.00201 0.00201	0.05016 0.00503 0.00383 0.00389	0.003250 0.00692 0.00648 0.00648	0.00387
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TABLE A-4 (Continued)

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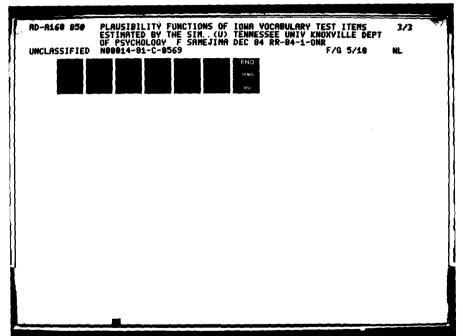
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0.00108 0.00688 0.00 0.00573 0.00543 0.00 0.00530 0.00643 0.00	0.00549 0.00931 0.00398 0.00549 0.02039 0.00578 0.00549 0.01349 0.00491	0.00298 0.00210 0.00 0.00215 (0.01927) 0.00 0.00219 0.00362 0.00 0.00781 0.00440 0.00	0.00354 0.00464 0.00 0.00296 0.00770 0.00 0.00210 0.00111 0.00 0.00672 0.00474 0.00	0.00497 0.00595 0.00 0.00497 0.01775 0.00 0.00480 0.01199 0.00	0.00345 0.00425 0.00305 0.00405 0.00346 0.00254 0.00213 0.01219 0.01735 0.00381 0.00585 0.00515	0.00257 0.00400 0.00177 0.00361 0.00752 0.00236 0.00206 0.00606 0.00238 0.00666 0.00423 0.00298	0.00487 0.00509 0.00363 0.00426 0.00728 0.00224 0.00289 0.00965 0.01810
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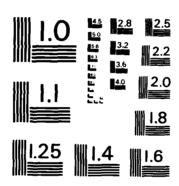
TABLE A-4 (Continued)

60 C.01430 0.00536 0.00535 0.00537 0.00578 0.00423 0.00578 0.00543 0.00515 0.00528 0.00515 0.00528 0.00515 0.00573 0.00558 0.00573 0.00558 0.00573 0.00558 0.00573 0.00534 0.00573 0.00534 0.00574 0.00534 0.00574 0.00534 0.00574 0.00536 0.00574 0.00536 0.00564	0.00741		*	GE LES	96900.0	0.00972	1,000	0.00524 0.00478
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61 Q111928 0.00573 0.00658 Q101038 0.00346 0.00688 0.00334 0.00688 0.00334 0.00688 0.00334 0.00688 0.00280 0.0029 0.00127 0.00159 0.00535 0.00564 0.00535 0.00564 0.00536 0.00564	0.00315 0.00407 0.00386 0.00350	0.003 1 0.00712 0.00474 0.00474	0.00350 0.00265 0.00235	0.00275 0.00932 0.00647 0.00249	0.00174 0.00247 0.00491	0.00207 0.004\$5 0.00394 0.00395	0.00214	0.00890 0.00273 0.00516 0.00244
62 0.00918 0.00206 0.00280 0.00298 0.017030 0.00129 0.00127 0.00224 63 0.00316 0.00224 63 0.00316 0.00261 0.00536 0.00561 0.00536 0.00561	0.00573 0.00946 0.00579 0.00359	0.00725 0.00545 0.00773 0.00489	0.00892 0.00481 0.00241	0.00593 0.00984 0.00519	0.00350 0.00405 0.00612 0.00395	0.00340	0.00605	0.00162
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1 65 00 -0	0.00487 0.00348 0.00497 0.00497	0.00310 0.00601 0.00751 0.00675	0.00250 0.00291 0.00478	0.00244	0.00193 0.0000 0.0000 0.0000	0.00262 0.00425 0.00345	0.00225 0.00741 0.00273 0.00197	
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6.00215.00.00220 0.00640 0.00571 0.00228 0.00313 0.00228 0.00432	0.00676 0.00460 0.00385 0.00481	0.00447	0.00444 0.00336 0.00217 0.00551	0.00313 0.00645 0.00468	0.00281 0.00349 0.00310	0.00289 0.00743 0.00279 0.00314	0.00274 0.00908 0.00467 0.00204	0.00695 0.00448 0.00521 0.00199

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